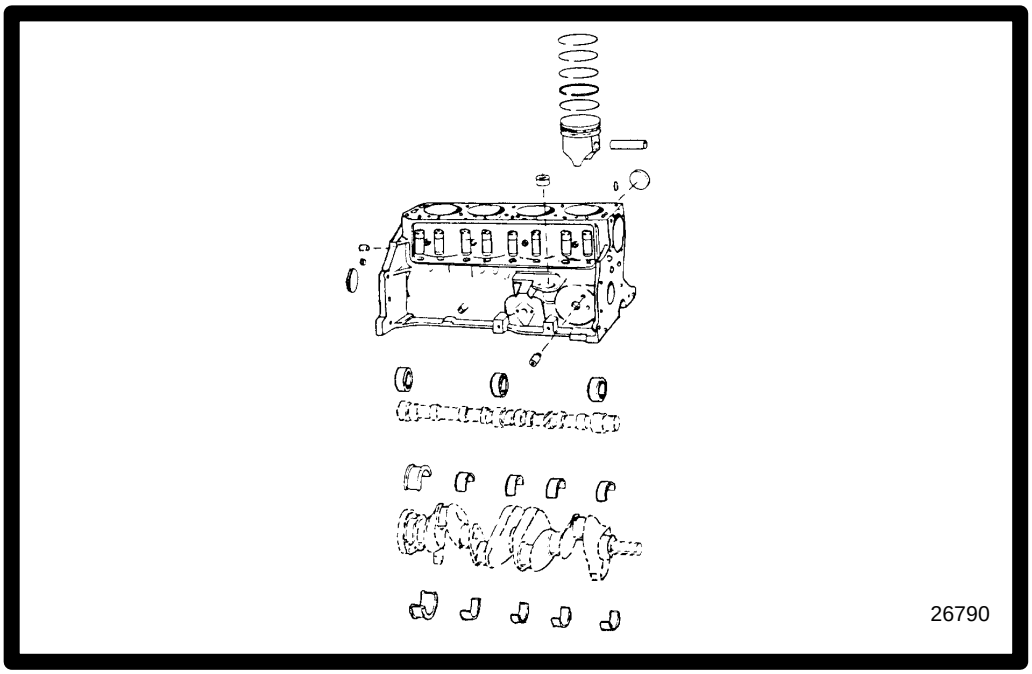
ENGINE

3

A



181 CID (3.0L) 4 CYLINDER GM ENGINE

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Torque Specifications

Fastener Location	Lb. In.	Lb. Ft.	N·m
Camshaft Sprocket Bolts	80		9
Connecting Rod Cap Nuts		45	61
Cylinder Head Bolts		90 Note 1	122
Distributor Clamp		20	27
Engine Coupler to Flywheel		35	47
Flywheel Housing to Block		21	28
Flywheel to Crankshaft Bolts		65	88
Front Cover Bolts	30		3.4
Front Mount to Block		21	28
Main Bearing Cap Bolts		65	88
Manifold to Head		23 Note 2	31
Oil Pan Bolts-Crankcase	80		9
Oil Pan Bolts -to Front Cover	45		5
Oil Pan Studs to Oil Seal Retainer or Crankcase	15		1.7
Oil Pump Cover	72		8
Oil Pump to Block	120		14
Oil Pump Pickup	60		7
Rocker Arm Cover and Bolts	40		4.5
Rear Crankshaft Oil Seal Retainer Nuts	135		15
Spark Plugs		22	30
Starter Motor to Block		37	50
Timing Gear Cover	72		8
Torsional Damper Bolt		50	68
Water Pump to Block		15	20

Note 1: Retorque after first 20 hours of operation.
Note 2: Retorque after first start up.

Tools/Lubricants/Sealants

MERCURY MARINE SPECIAL TOOLS	
91-24697	Piston Ring Expander
91-63209	Torch Lamp

KENT MOORE SPECIAL TOOLS	
J5892	Valve Spring Compressor (Head on)
J8062	Valve Spring Compressor (Head off)
J23738-A	Valve Stem Seal Tester
J8101	Valve Guide Cleaner
J8814	Valve Guide Reamer (Standard)
J5830-02	Valve Guide Reamer (.015 in. oversize)
J5802-01	Rocker Arm Stud Remover
J6880	Rocker Arm Stud Installer
J5715	Stud Bore Reamer (.003 in. oversize)
J6036	Stud Bore Reamer (.013 in. oversize)
J8089	Carbon Remover Brush
J5910-04	Piston Support Tool
J24086-B	Piston Pin Tool
J3936-03	Piston Ring Groove Cleaner
J8037	Piston Ring Compressor
J5239	Connecting Rod Guide Tool (3/8 -24)
J8087	Cylinder Bore Checker
J8369	Oil Pump Suction Pipe Installer
J23042-B	Timing Cover Seal Aligner
J8520	Cam Lobe Lift Indicator
J6098-01	Camshaft Bearing Installer/Remover Tool
J9534-01	Distributor Shaft Lower Bearing Installer/Remover
J6978-E	Pulley Hub Puller
J5590	Pulley Hub Installer
J24420-B	Universal Torsional Damper Remover

LUBRICANTS/SEALANTS	
92-34227--1	Quicksilver Perfect Seal
92-825407A12	Quicksilver 2-C-4 Marine Lubricant with Teflon
92–91601-1	Quicksilver RTV Sealer

Engine Specifications

UNIT OF MEASUREMENT in. (mm)

Model	3.0L/3.0LX
Displacement	181 CID (3.0L)

CYLINDER BORE

Diameter			3.9995-4.0025(101.588-101.790)
Out of Round		Production	.0005(0.012) Max
		Service	.002(0.05) Max
Taper	Production	Thrust Side	.0005(0.012) Max
		Relief Side	.0005(0.012) Max
	Service		.001(0.02) Max

PISTON CLEARANCE

Production	.0025-.0035(0.064-0.088) Max
Service	.0035(0.08) Max

PISTON RING: COMPRESSION

Groove Clearance	Production	Top	.0012-.0029(0.030-0.073)
		2nd	
	Service		.003(0.09) Max
Gap	Production	Top	.010-.020(0.254-0.762)
		2nd	
	Service		.035(0.88) Max

PISTON RING: OIL

Groove Clearance	Production	.001-.006(0.026-0.152)
	Service Limit	.007(0.17) Max
Gap	Production	.010-.030(0.254-0.762) Max
	Service Limit	.040(1.01) Max

PISTON PIN

Diameter		.9270-.9271(23.546-23.550)
Clearance	Production	.0003–.0006(0.008-0.016)
	Service Limit	.001(0.02) Max
Fit in Rod		.0008-.0019(0.020-0.050) Interference

CRANKSHAFT

Main Journal	Diameter		2.2979-2.294(58.367-58.404)
	Taper	Production	.0002(0.005) Max
		Service	.001(0.02) Max
	Out of Round	Production	.0002(0.005) Max
		Service	.001(0.02) Max
Main Bearing Clearance	Production	No.1-No.4	.001-.0024(0.025-0.060)
	Service	No.5	.0016-.0035(0.041-0.088)
	Production	No.1-No.4	.001-.0025(0.03-0.06)
	Service	No.5	.002-.0035(0.05-0.08)
Crankshaft End Play			.002-.006(0.05-0.15)
Crankpin	Diameter		2.09980-20995(53.289-53.327)
	Taper	Production	.0003(0.007) Max
		Service	.001(0.02) Max
	Out of Round	Production	.0002(0.51) Max
		Service	.001(0.02) Max
Rod Bearing Clearance	Production		.0017-.0027(0.044-0.0686)
	Service		
Rod Size Clearance			.006-.017(0.153-0.4318) Max

CAMSHAFT

Lobe Lift (Max.)	Intake	.2529(6.425)
	Exhaust	.2529(6.425)
Journal Diameter		1.8677-18697(47.440-47.490)
Camshaft End Play		.003-.008(0.08-0.2032) Max

CYLINDER HEAD

Gasket Surface Flatness	.003-.008in any 6 in.(152) or .007(0.15) Overall Max

VALVE SYSTEM

Lifter			Hydraulic
Rocker Arm Ratio			1.75 to 1
Collapsed Tappet Gap			3/4 Turn Down from Zero Lash
Face Angle		Intake	45°
		Exhaust	45°
Seat Angle (Intake & Exhaust)			46°
Seat Runout (Intake & Exhaust)			.002(0.05) Max
Seat Width		Intake	1/16 (.0625in). (1.16 mm)
		Exhaust	1/16-5/64 [.0625-.07812 in.] (1.6-2.0 mm)
Stem Clearance	Production	Intake	.0010-.0027(0.025-0.069)
		Exhaust	.0007-.0027(0.018-0.069)
	Service	Intake	.003(0.09) Max
		Exhaust	.004(0.11) Max
Spring	Free Length		2-1/16 in. (52 mm)
	Pressure	Valve Closed	100-110 lb. (136-149 N) at 1-19/32 in. (41 mm)
		Valve Open	208-220 lb. (282-300 N) at 1-7/32 in. (31 mm)
	Installed Height ± .031(8)	Intake	(1/32)1.6562(42)
		Exhaust	
Internal Damper			None

General

Some of the repairs in this section must be completed with engine removed from boat. Engine removal depends upon type of repair and boat design. Place engine on repair stand for major repairs.

When engine removal is not required, make certain that battery cables are disconnected at the battery prior to performing any on-board engine repair procedure.

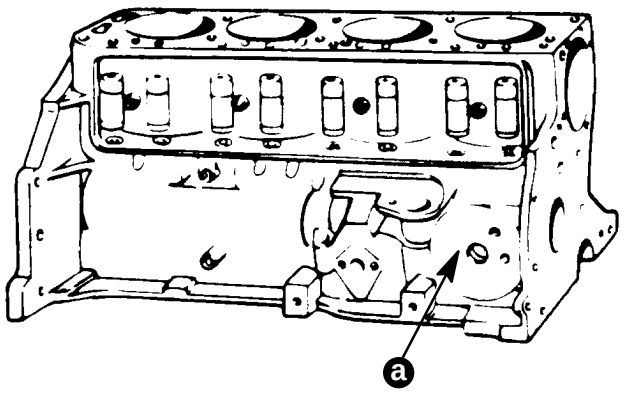
Lubricate all moving parts (during reassembly) with engine oil. Apply Quicksilver Perfect Seal on threads of and under heads of cylinder head bolts, and on threads of all cylinder block external bolts, screws and studs.

Model	No. of Cylinders	Cu. In./Litres Displacement
MCM 3.0L/3.0LX	4	181 (3L)

Engine Identification

The MerCruiser Model can be determined by looking at the LAST TWO LETTERS of the engine code stamped into the cylinder block. This code number is stamped on all MerCruiser power packages and replacement partial engines, but not replacement cylinder block assemblies.

If the engine serial number and/or model decals are missing, the engine code letters may help in determining the engine models.



74520

3.0L uses the 2.5L cylinder head
3.0LX uses the 3.0L cylinder head

a - 4 Cylinder-In-Line Engine Code (Next To Distributor)

G.M. Engine Code Location
MCM Stern Drive Engines (LH Rotation)
3.0L - RM, RJ
3.0LX - RN, RK

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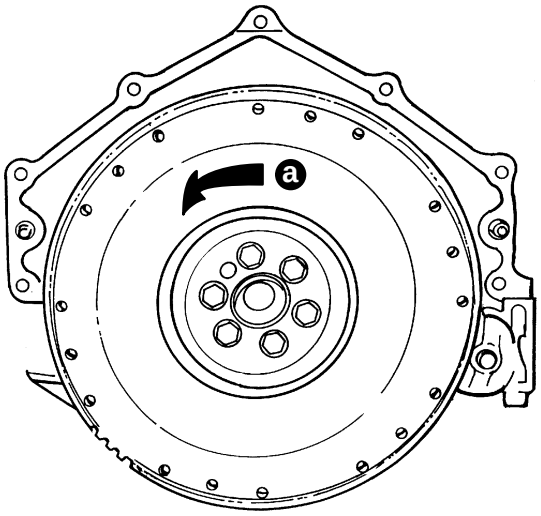
Engine Rotation

Engine rotation terminology at times has caused confusion. To clarify, engine rotation is determined by observing flywheel rotation from the rear (transmission or stern drive end) of the engine looking forward (water pump end).

PROPELLER ROTATION IS NOT NECESSARILY THE SAME as engine rotation. Do not rely on propeller rotation in determining engine rotation.

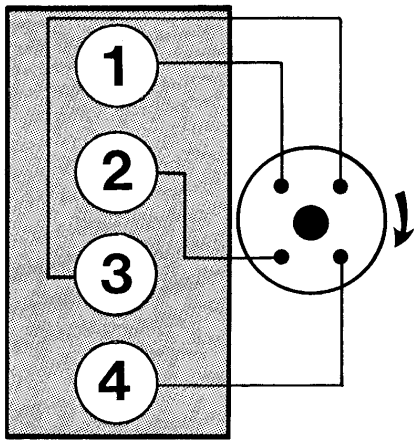


72001

a - Left-Hand Rotation (CCW) - All Stern Drive Engines

Firing Order

1-3-4-2

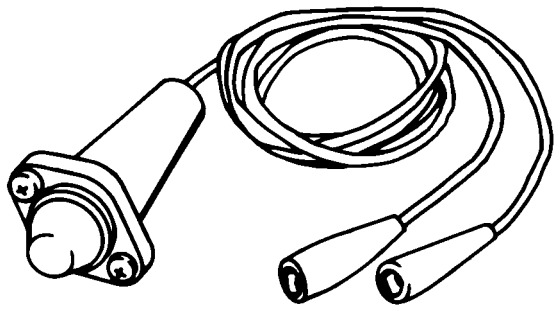


Priming Engine With Oil

IMPORTANT: This applies to all power packages that have not been run within 6 months, replacement of partial engines or after rebuilding an engine.

Tool Required

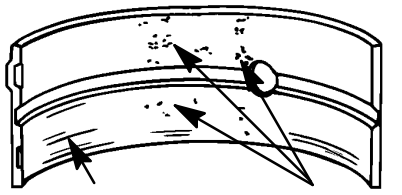
91-52024A1 Remote Starter Kit



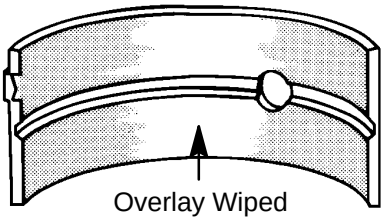
71089

1. Fill crankcase to proper level with the recommended engine oil.
2. Remove spark plugs.
3. Leave ignition key in ”OFF” position.
4. Connect remote starter switch (91-52024A1) to large 12 V terminal (RED battery cable) and small terminal (RED/YELLOW) wire on starter motor.
   a. If remote starter switch is not available, disconnect PURPLE wire from ignition coil before using key switch to crank the engine over. Tape terminal on PURPLE wire to prevent it from touching ground.
5. Crank engine for 15 seconds, then allow starter motor to cool down for 1 minute. This should prevent starter motor from overheating.
6. Repeat this process until a total of 45 seconds of cranking time is achieved.
7. Remove remote starter switch.
   a. If key switch was used, reconnect PURPLE wire to ignition coil.
8. Install spark plugs and wires
9. Supply cooling water to seawater pump and start motor.

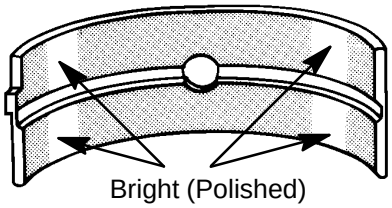
Bearing Failures



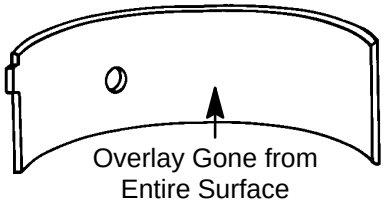
Scratched by Dirt



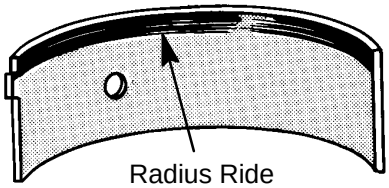
Lack of Oil



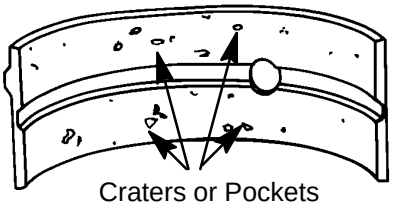
Improper Seating



Tapered Journal



Radius Ride



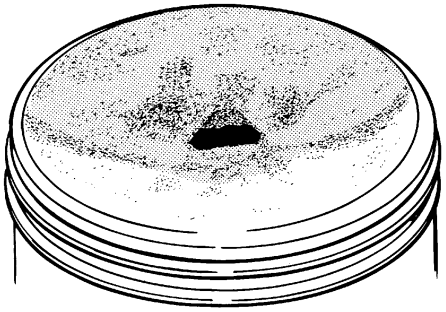
70436

Fatigue Failure

Piston Failures

Pre-Ignition

Pre-ignition is abnormal fuel ignition, caused by combustion chamber hot spots. Control of the start of ignition is lost, as combustion pressure rises too early, causing power loss and rough running. The upward motion on the piston is opposed by the pressure rise. This can result in extensive damage to the internal parts from the high increase in combustion chamber temperature.



72424

Pre-Ignition Damage

PRE-IGNITION CAUSES

1. Hot spots in the combustion chamber from glowing deposits (due in turn to the use of improper oils and/or fuels).
2. Overheated spark plug electrodes (improper heat range or defective plug).
3. Any other protuberance in the combustion chamber, such as an overhanging piece of gasket, an improperly seated valve or any other inadequately cooled section of material which can serve as a source.

Engine failures, which result from the foregoing conditions, are beyond the control of Mercury Marine; therefore, no warranty will apply to failures which occur under these conditions.

Detonation

Detonation, commonly called “fuel knock,” “spark knock” or “carbon knock,” is abnormal combustion of the fuel which causes the fuel to explode violently. The explosion, in turn, causes overheating or damage to the spark plugs, pistons, valves and, in severe cases, results in pre-ignition.

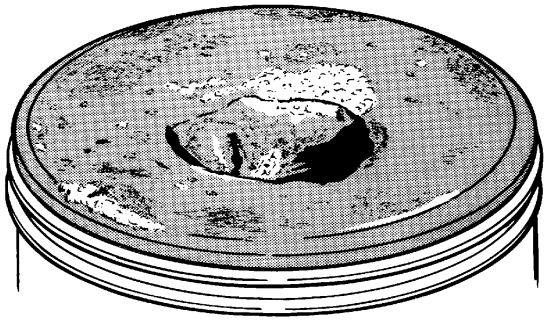
Use of low octane gasoline is one of the most common causes of detonation. Even with high octane gasoline, detonation could occur if engine maintenance is neglected.

OTHER CAUSES OF DETONATION

IMPORTANT: Use of improper fuels will cause engine damage and poor performance.

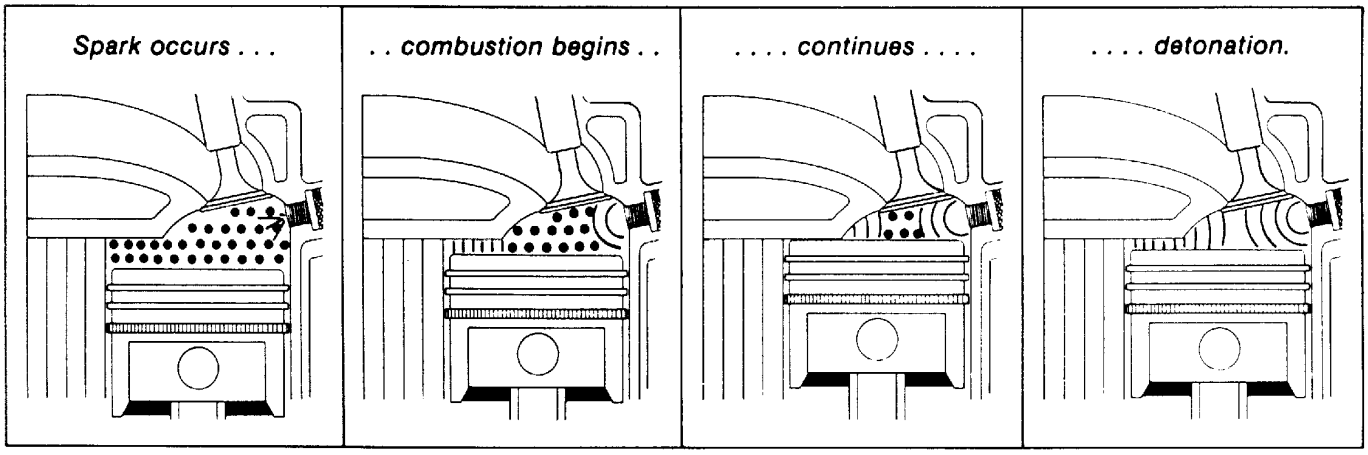
1. Over-advanced ignition timing.
2. Lean fuel mixture at or near full throttle (could be caused by carburetor or leaking intake manifold).
3. Cross-firing spark plugs.
4. Excess accumulation of deposits on piston and/or combustion chamber (results in higher compression ratio).
5. Inadequate cooling of engine by deterioration of cooling system.

Engine failures, which result from the foregoing conditions, are beyond the control of MerCruiser; therefore, no warranty will apply to failures which occur under these conditions.



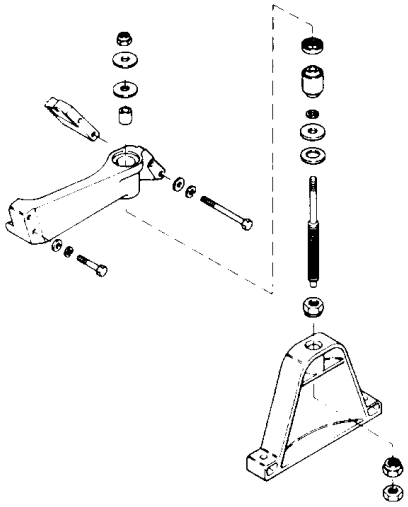
72425

Detonation Damage



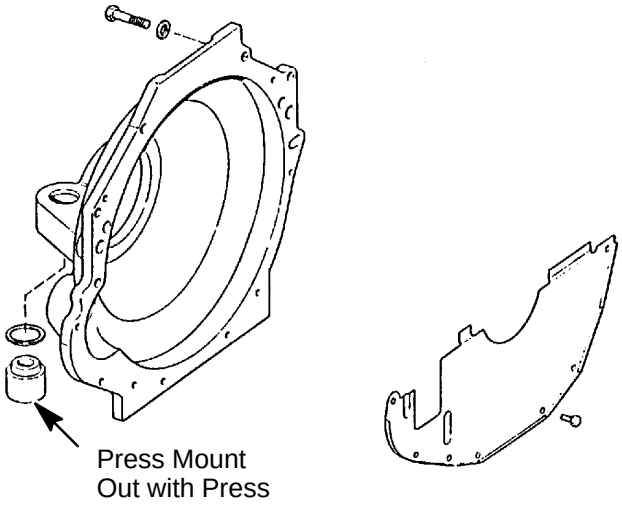
72315

Engine Mounts



74275

Front Mount



72318

Rear Mount/Flywheel Housing

Rocker Arm Cover

Removal

It may be necessary to remove exhaust manifold before removing rocker arm cover. Refer to Section 7B for removal.

1. Disconnect crankcase ventilation hoses.
2. Remove any items that interfere with the removal of rocker arm covers.

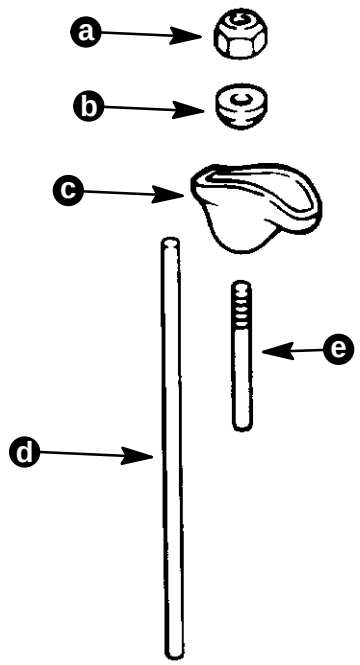
IMPORTANT: DO NOT pry rocker arm cover loose. Gaskets, which may adhere to cylinder head and rocker arm cover, may be loosened by bumping end of rocker cover from the rear with palm of hand or a rubber mallet.

3. Remove rocker arm cover.

Installation

1. Clean sealing surfaces on cylinder head and rocker arm cover with degreaser.
2. Place new rocker arm cover gasket in position in rocker arm cover.
3. Install rocker arm cover. Torque screws to 40 lb. in. (4.5 N·m).
4. Install exhaust manifolds, if removed.
5. Install any items which were removed to allow removal of rocker arm covers.
6. Connect crankcase ventilation hoses to rocker arm covers.

Rocker Arm/Push Rod



74287

Valve Mechanism

a - Nut
b - Ball Unit
c - Rocker Arm
d - Push Rod
e - Rocker Arm Stud

Removal

NOTE: *When servicing only one cylinder's rocker arms, bring that cylinder's piston up to TDC before removing rocker arms. When servicing all rocker arms, bring No. 1 piston up to TDC before removing rocker arms.*

1. Remove rocker arm covers as outlined.
2. Remove rocker arm assemblies and push rods.

IMPORTANT: Place rocker arm assemblies and push rods in a rack for reassembly in their original locations.

Cleaning and Inspection

1. Clean parts with solvent and dry with compressed air.
2. Inspect all contact surfaces for wear. Replace all damaged parts.

Installation

IMPORTANT: When installing rocker arms and rocker arm balls, coat bearing surfaces of rocker arms and rocker arm balls with engine oil.

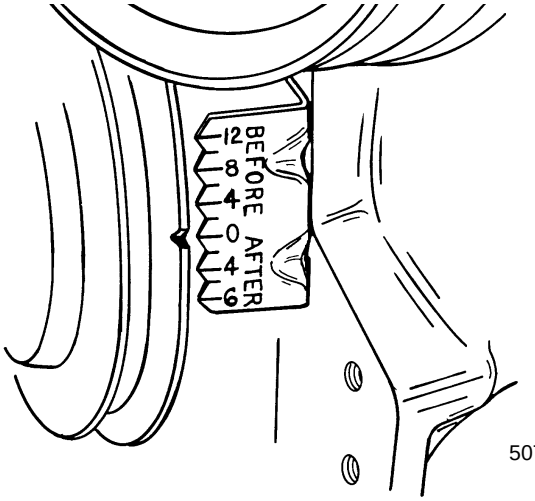
1. Install push rods in their original locations. Be sure push rods seat in lifter socket.
2. Install rocker arms, rocker arm balls and rocker arm nuts in their original locations.
3. Torque rocker arm nuts to 20 lb. ft. (27 N·m). No valve adjustment is required. Valve lash is automatically set when rocker arm nuts are torqued to specification.
4. Adjust carburetor idle speed and mixture.

Valve Adjustment

Engine Not Running

With valve cover removed, adjust valves when lifter is on low part of camshaft lobe, as follows:

1. Crank engine with starter or turn over in normal direction of rotation until mark on torsional damper lines up with center “0” mark on timing tab, and engine is in No. 1 firing position. This may be determined by placing fingers on No. 1 valve as mark. If valves move as mark comes up to timing tab, engine is in No.4 firing position and should be turned over one more time to reach No. 1 position.



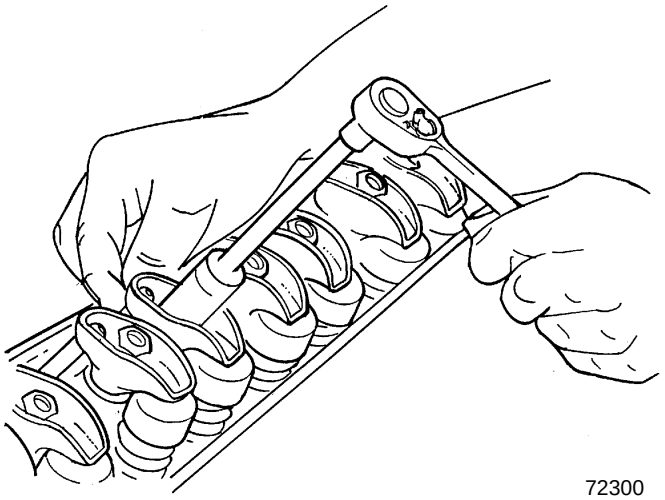
50770

No. 1 Cylinder - Exhaust and Intake
No. 2 Cylinder - Intake
No. 3 Cylinder - Exhaust
No. 4 Cylinder - Intake

2. With engine in No. 1 firing position as determined above, the following valves may be adjusted:
3. Back out adjusting nut until lash is felt at push rod, then turn in adjusting nut until all lash is removed. This can be determined by moving push rod up-and-down while turning adjusting nut until all play is removed.
4. Hydraulic lifters now can be adjusted by tightening adjustment nut an additional 3/4-turn. Valve lash should be checked after engine has run and reached operating temperature.
5. Crank engine one revolution until pointer “0” mark and torsional damper mark are again in alignment. This is No. 4 firing position. With engine in this position, the following valves may be adjusted:

No. 2 Cylinder - Exhaust
No. 3 Cylinder - Intake
No. 4 Cylinder - Exhaust

6. Install distributor cap, spark plug wires and coil lead.
7. Install rocker arm cover; torque to 40 lb. in. (4.5 N·m).


72300

Engine Running

Following procedure should be completed only if readjustment is required.

1. Run engine until it reaches normal operating temperature, then remove valve cover.
2. With engine running at idle, back off valve rocker arm nut until valve rocker arm starts to clatter.
3. Turn rocker arm nut down slowly until clatter just stops. This is zero lash position.
4. Turn nut down 1/4 additional turn and pause 10 seconds until engine runs smoothly. Repeat additional 1/4 turns, pausing 10 seconds each time, until nut has been turned down 3/4 turn from zero lash position.

IMPORTANT: The following preload adjustment must be done slowly to allow lifter to adjust itself, thus preventing possibility of the valve head contacting the top of piston, which may result in internal damage and/or bent push rods.

Index

5. Repeat Steps 2-3-4 to adjust other valves.
6. Install valve covers, torque screws to 40 lb. in. (4.5 N·m).
7. Adjust carburetor idle mixture and idle speed. Check for leaks.

Hydraulic Valve Lifters

Hydraulic valve lifters require little attention. Lifters are extremely simple in design. Normally, readjustments are not necessary and servicing requires only that care and cleanliness be exercised in the handling of parts.

Locating Noisy Lifters

Locate a noisy valve lifter by using a piece of garden hose approximately 4 ft. (1.2 m) in length. Place one end of hose near end of each intake and exhaust valve, with other end of hose to the ear. In this manner, sound is localized, making it easy to determine which lifter is at fault.

Another method is to place a finger on face of valve spring retainer. If lifter is not functioning properly, a distinct shock will be felt when valve returns to its seat.

General types of valve lifter noise are as follows:

1. Hard rapping noise - usually caused by plunger becoming tight in bore of lifter body so that return spring cannot push plunger back up to working position. Probable causes are:
   a. Excessive varnish or carbon deposit, causing abnormal stickiness.
   b. Galling or “pickup” between plunger and bore of lifter body, usually caused by an abrasive piece of dirt or metal wedged between plunger and lifter body.
2. Moderate rapping noise - probable causes are:
   a. Excessively high leakdown rate.
   b. Leaky check valve seat.
   c. Improper adjustment.
3. General noise throughout valve train - this will, in most cases, be a definite indication of insufficient oil supply or improper adjustment.
4. Intermittent clicking - probable causes are:
   a. A microscopic piece of dirt momentarily caught between ball seat and check valve ball.
   b. In rare cases, ball itself may be out of round or have a flat spot.
   c. Improper adjustment.

In most cases, where noise exists in one or more lifters, all lifter units should be removed, disassembled, cleaned in solvent, reassembled and reinstalled in engine. If dirt, corrosion, carbon, etc., is shown to exist in one unit, it more likely exists in all the units; thus it would only be a matter of time before all lifters caused trouble.

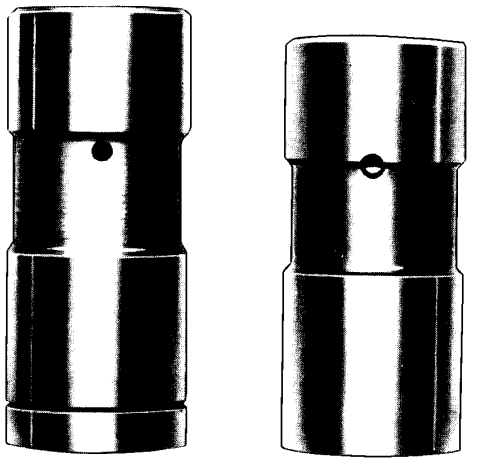
Removal

1. Remove as previously outlined:
   a. Rocker arm covers.
   b. Intake manifold.

IMPORTANT: Keep valve push rod and hydraulic lifter from each valve together as a matched set and mark or store them so they can be reinstalled in the same location later.

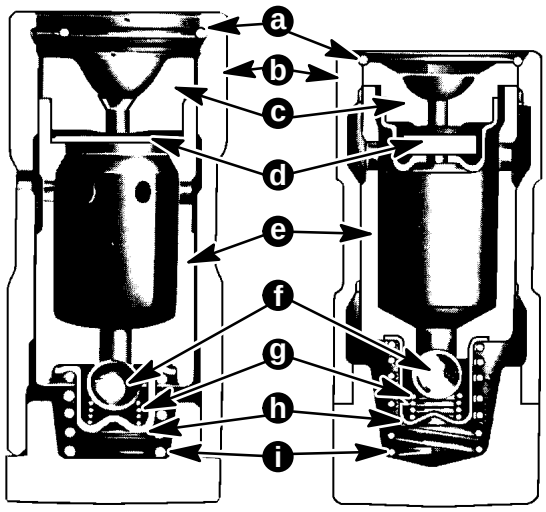
   c. Rocker arm assemblies and push rods.
2. Remove fasteners from lifter retainers (restrictors) and remove retainers. Do not disturb lifters at this time.

3. Make matching marks on all retainers and lifters as to location and orientation in bores, to allow reassembly in exact position on camshaft lobes (so that the roller's bearing and roller will roll in the same direction on the same lobe, if reused). Remove valve lifters.



05030

LIFTER "A" LIFTER "B"



05030

LIFTER "A" LIFTER "B"

a - Push Rod Seat Retainer
b - Lifter Body
c - Push Rod Seat
d - Metering Valve (Lifter "A")
Inertia Valve (Lifter "B")
e - Plunger
f - Check Ball
g - Check Ball Spring
h - Check Ball Retainer
i - Plunger Spring

Cleaning and Inspection

1. Thoroughly clean all parts in cleaning solvent and inspect them carefully.
2. If any parts are damaged or worn, entire lifter assembly should be replaced.
3. If outer lifter body wall is scuffed or worn, inspect cylinder block lifter bore.
4. If push rod seat is scuffed or worn, inspect push rod.

Installation

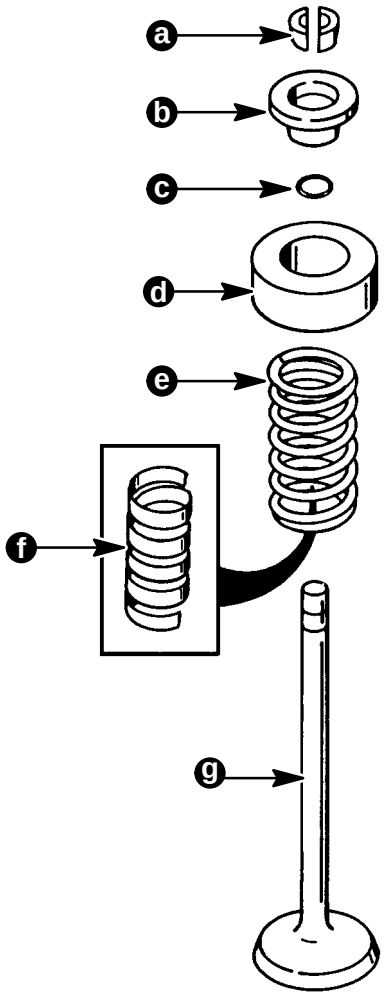
IMPORTANT: It is recommended that the engine oil be changed and a new oil filter be installed whenever servicing valve lifters or camshaft.

IMPORTANT: Before installing lifters, coat the lifter with engine oil. If new lifters or a new camshaft have been installed, an additive containing EP lube (such as General Motors Cam and Lifter Prelube or equivalent) should be poured over camshaft lobes before installing lifters.

IMPORTANT: DO NOT install used valve lifters if a new camshaft has been installed.

1. Install valve lifters into bores.
2. Install push rod covers, using new gaskets and torque to specification.
3. Install distributor, positioning rotor to number 1 cylinder position, then connect primary lead at coil.
4. Install distributor cap and spark plug wires.
5. Adjust valves to specifications.
6. Adjust ignition timing, carburetor idle speed and mixture.

Valve Stem Oil Seal/Valve Spring

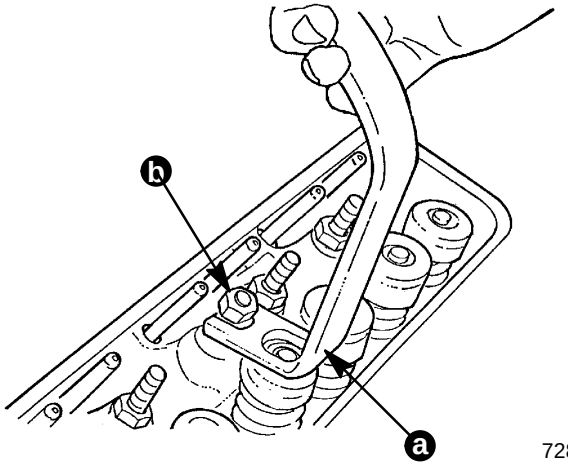


50841

a - Keys (2 per Valve)
b - Cap
c - Seal (On LX **Models**, These Are Used Only On Intake Valve Stems **Do Not** Install Them On Exhaust Valve Stems)
d - Valve Spring Shield
e - Valve Spring
f - Damper, Internal
g - Valve

Replacement Oil Seal Head Installed

1. Remove rocker arm cover.
2. Remove spark plug, rocker arm and push rod on cylinder to be serviced.
3. Place piston for that cylinder at TDC to prevent valves from dropping into the cylinder.
4. Compress valve spring with tool (J-5892) and remove valve keys, valve spring cap, spring shield and valve spring.



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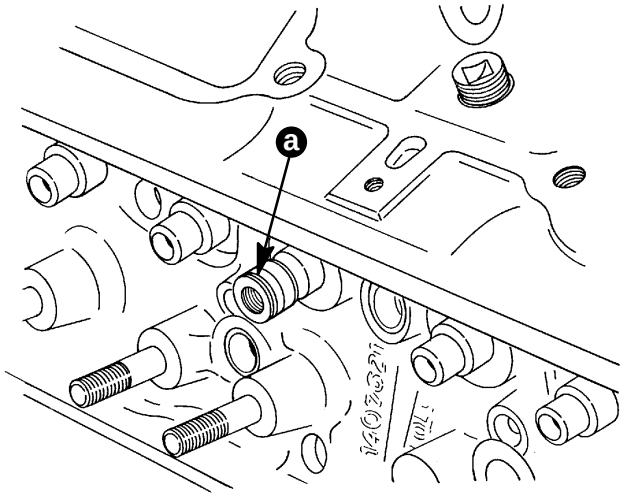
a - Valve Spring Compressor (J-5892)
b - Rocker Arm Nut

5. Remove valve stem oil seal.



72330

a - Valve Guide Seal

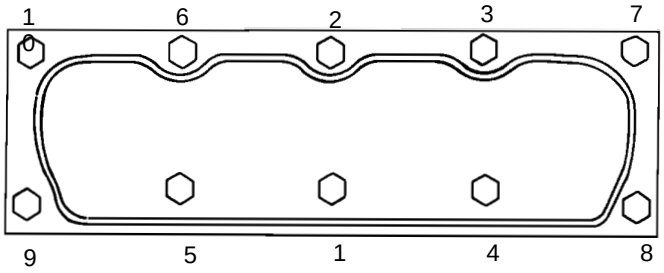
6. To install, set valve spring, (close, coiled end of spring is installed against cylinder head) valve shield and valve cap in place. Compress spring with tool (J-5892) and install oil seal in lower groove of stem, making sure that seal is flat and not twisted.

NOTE: *A light coat of oil on seal will help prevent twisting when compressor tool is released.*

IMPORTANT: Do not turn crankshaft while valve springs, retainers, and locks are removed or valves will fall into cylinder.

7. Install valve keys and release compressor tool. Be sure that keys seat properly in upper groove of valve stem.
8. Install push rods and rocker arm assemblies.
9. Torque rocker arm nuts to 20 lb. ft. (27 N·m).
10. Install rocker arm cover and torque to 40 lb. in. (4.5 N·m). Install spark plug, and torque to 15 lb. ft. (20 N·m).
11. Install spark plug and torque to specifications.
12. Repeat steps 2 thru 8 for other cylinders.

Cylinder Head



Cylinder Head Torque Sequence

1. Drain engine cooling system.
2. Remove as outlined:
   a. Exhaust manifolds.
   b. Intake manifold.
   c. Rocker arm covers.
   d. Rocker arm assemblies and push rods (keep in order for reassembly in their original locations).
   e. Any components attached to front or rear of cylinder head.
   f. Spark plugs.
   g. Head bolts.

⚠CAUTION

The head gasket may be holding cylinder head to block. Use care when prying off cylinder heads. DO NOT damage gasket surfaces. DO NOT drop cylinder heads.

3. Place cylinder head on wooden blocks to prevent damage to gasket surfaces.

Cleaning and Inspection

1. Clean gasket material and sealer from engine block and cylinder heads.
2. Inspect sealing surfaces for deep nicks and scratches.
3. Inspect for corrosion around cooling passages.
4. Clean head bolt threads and engine block bolt hole threads, making sure no dirt, old oil or coolant remain.

Installation

⚠CAUTION

When using ribbed stainless steel head gaskets, apply a thin coating of Quicksilver Perfect Seal to both sides of gasket. Too much sealer may hold gasket away from head or block causing leakage. DO NOT use sealer on graphite composition head gaskets.

1. Place head gasket in position over dowel pins.
2. Carefully set cylinder head in place over dowel pins.
3. Coat threads of head bolts with Quicksilver Perfect Seal and install finger-tight.
4. To insure gasket sealing, torque head bolts in torque sequence to 90 lb. ft. (122 N·m).
5. Install push rods, rocker arm assemblies and lifter restrictors in their original positions.
6. Torque rocker arm nuts to 20 lb. ft. (27 N·m).

7. Install as outlined:
   a. Intake manifold.
   b. Rocker arm covers.
   c. Exhaust manifolds.
   d. Spark plugs.
   e. Any components removed from front or rear of cylinder heads.
8. Follow procedures in SECTION 6A or 6B of this manual:

   Seawater Cooled Models: Provide for adequate water supply to seawater pickup (see SECTION 6A).

   Closed Cooled Models: Refill closed cooling section (see SECTION 6B), and provide adequate water supply to seawater pickup.

⚠CAUTION

Ensure that cooling water supply is available before starting the engine.

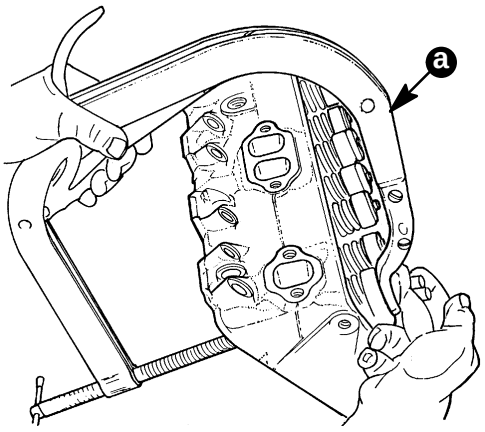
9. Start engine, set timing, set idle speed, and check for leaks.

Cylinder Head and Valve Conditioning

Disassembly

NOTE: *On LX models, O-ring seals are used only on intake valve stems.*

1. Using valve spring compressor, compress valve spring (J-8062) and remove valve locks. Slowly release tool.
2. Remove all valve components.
3. Remove valves from cylinder head and place in a rack, in order, for reassembly in their original locations.

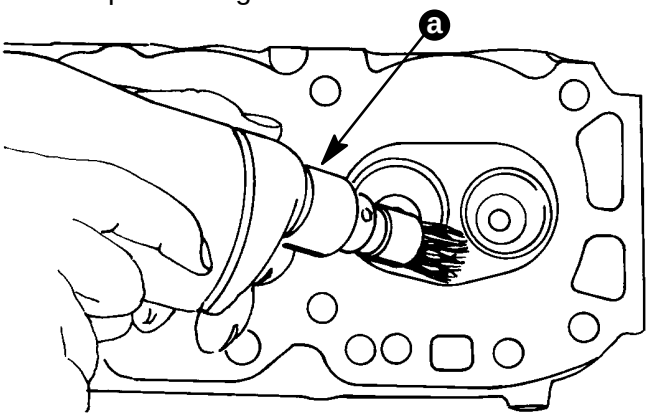


72333

a - Valve Spring Compressor (J-8062)

Cleaning

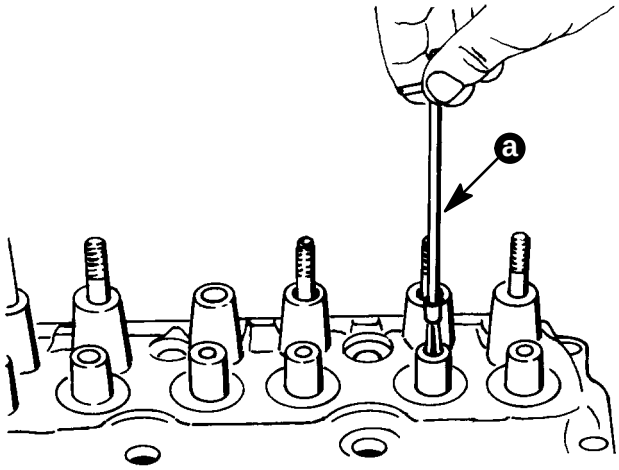
1. Clean push rods and rocker arm assemblies.
2. Clean carbon from valves using tool (J-80890).
3. Clean gasket material from cylinder head mating surfaces.
4. Clean all carbon from combustion chambers and valve ports using carbon remover brush.



74274

a - Carbon Remover Brush (J-8089)

5. Thoroughly clean valve guides with valve guide cleaner (J-8101).

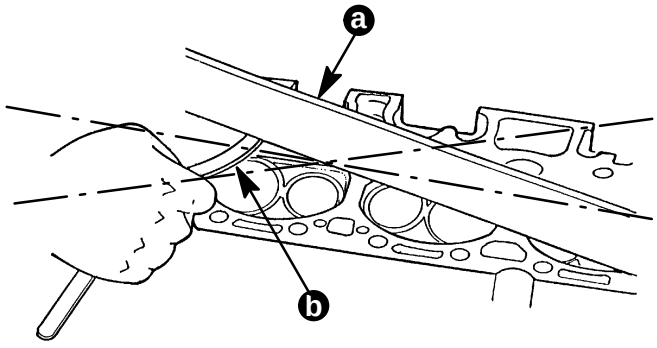


74286

a - Valve Guide Cleaner (J-8101)

Inspection

1. Inspect cylinder head for cracks in exhaust ports, water jackets, and combustion chambers (especially around spark plug holes and valve seats). Replace heads if any cracks are found.
2. Inspect cylinder head gasket surface for burrs, nicks, or erosion or other damage. Also, check flatness of cylinder head gasket surface, using a machinist's straight edge and feeler gauges as shown. Refer to "Specifications."



72885

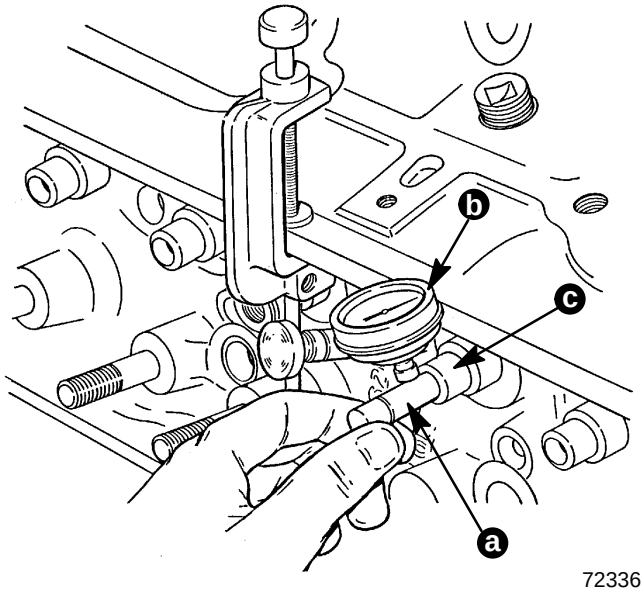
a - Straight Edge
b - Feeler Gauge
c - Take Measurements Diagonally Across Head (Both Ways) and Straight Down Center Head

IMPORTANT: Cylinder head-to-block gasket surface should be resurfaced if warped more than specified. When head resurfacing is required, cylinder head-to-intake manifold gasket surface on head must be milled to provide proper alignment between intake manifold and head.

3. Inspect valves for burned heads, cracked faces or damaged stems.

IMPORTANT: Excessive valve stem to bore clearance will cause excessive oil consumption and possible valve breakage. Insufficient clearance will result in noisy and sticky valves.

4. Measure valve stem clearance as follows:
   a. Attach a dial indicator to cylinder head, positioning it against the valve stem and close to the valve guide.
   b. Holding valve head off seat about 1/16 in. (2 mm), move valve stem back and forth in direction shown. Compare stem clearance with specifications.
   c. If clearance exceeds specifications, it will be necessary to ream valve guides for oversized valves, as outlined under "Valve Guide Bore Repair."



72336

a - Valve Stem
b - Dial Indicator
c - Valve Guide

Rocker Arm Studs

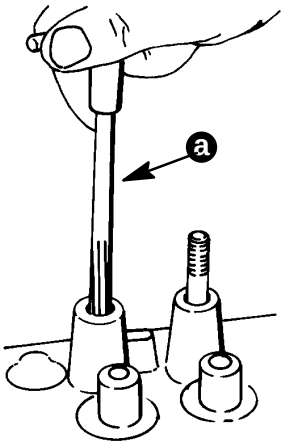
Rocker arm studs with damaged threads or with loose fit in cylinder heads should be replaced with new, oversize studs. Studs may be installed after reaming holes as follows:

1. Drain water from cylinder block.
2. Remove old stud by placing Tool J-5802-01 over stud, installing nut and flat washer and removing stud by turning nut.

74288

a - Tool J-5802-01

3. Ream hole for oversize stud with Tool J-5715 for .003 in. oversize or Tool J-6036 for .013 in. oversize.



74289

a - Reamer Tool J-5715

IMPORTANT: Do not attempt to install an oversize stud without reaming stud hole.

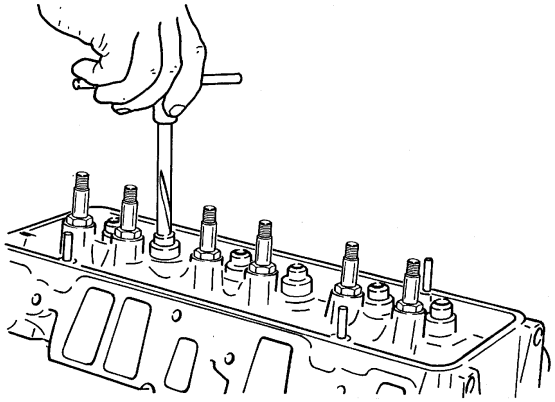
4. Coat press-fit area of stud with Perfect Seal. Install new stud, using Tool J-6880 as a guide. Gauge should bottom on head.

Valve Guide Bore Repair

IMPORTANT: Be sure to measure valve stem diameter of both the intake and exhaust valve, as valve stem diameter may or may not be the same for both valves.

If .015 in. oversize valve stems are required, ream valve guide bores for oversize valves, as follows:

1. Measure valve stem diameter of old valve being replaced and select proper size valve guide reamer from chart below.
2. Ream valve guide bores, as shown.



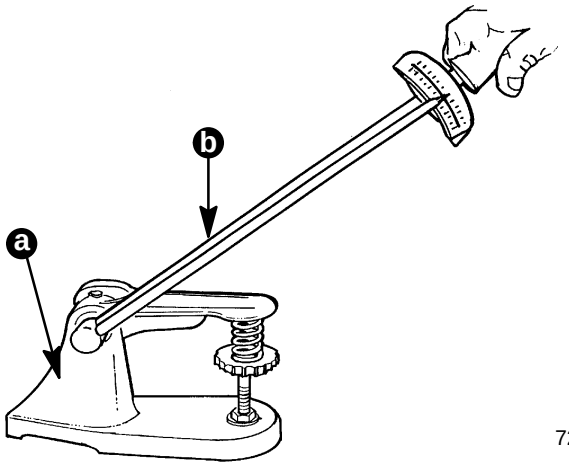
72886

3. Remove the sharp corner created by reamer at top of valve guide.

Valve Springs - Checking Tension

Using valve spring tester, as shown, check valve spring tension with dampers removed. Refer to “Specifications.”

IMPORTANT: Springs should be replaced if not within 10 lbs. (44 N) of specified tension.



72308

a - Valve Spring Tester (J-8056)
b - Torque Wrench

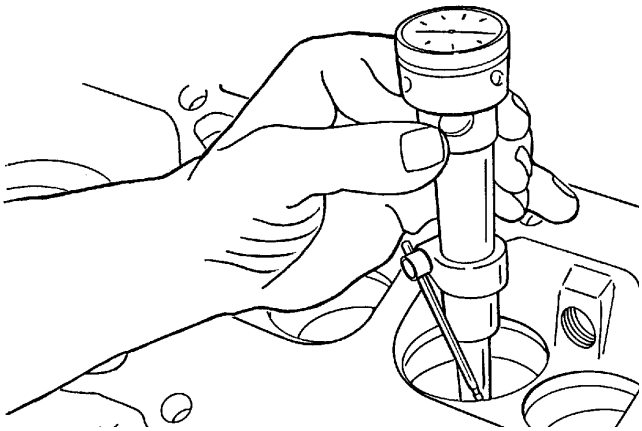
Valve Seats

Valve seat reconditioning is very important, since seating of valves must be perfect for engine to deliver maximum power and performance.

Another important factor is valve head cooling. Good contact between each valve and its seat in head is important to ensure that heat in valve head will be properly dispersed.

Several different types of equipment are available for reseating valve seats. Equipment manufacturer's recommendations should be followed carefully to attain proper results.

Regardless of type of equipment, however, it is essential that valve guide bores be free from carbon or dirt to achieve proper centering of pilot in valve guide, ensuring concentricity.

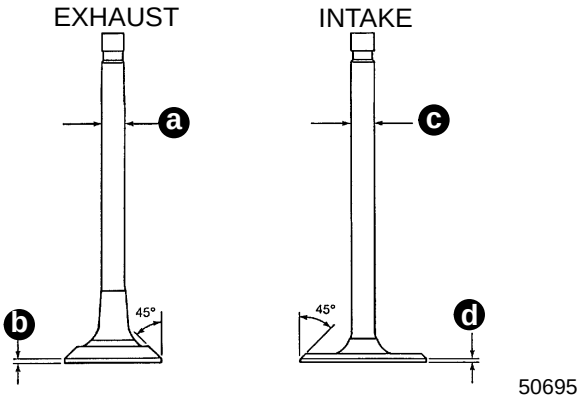


72338

a - Check Valve Seat Concentricity

Valves that are pitted must be refaced to the proper angle. Valve stems which show excessive wear, or valves that are warped excessively, must be replaced. When a valve head which is warped excessively is refaced, a knife edge will be ground on part or all of the valve head, due to the amount of metal that must be removed to completely reface. Knife edges lead to breakage, burning, or pre-ignition due to heat localizing on this knife edge. If the edge of the valve head is less than 1/32 in. (0.8 mm) after grinding, replace the valve.

Several different types of equipment are available for refacing valves. The recommendation of the manufacturer of the equipment being used should be carefully followed to attain proper results.



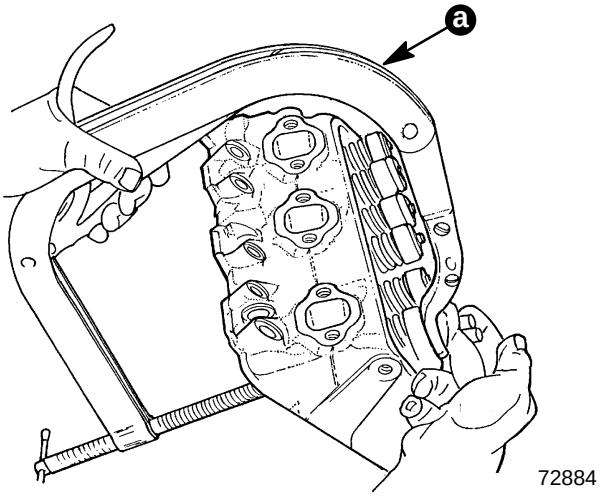
50695

Exhaust
a - .372 In. (9.45 mm)
b - 1/32 [.031] In. (0.79 mm) Min.
Intake
c - .341 In. (8.16 mm)
d - 1/32 [.031] In. (0.79 mm) Min.

Reassembly

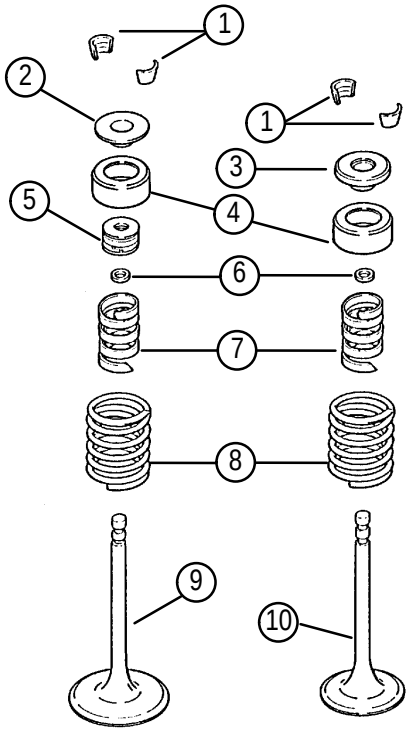
1. Lubricate valve guides and valve stems with engine oil.
2. Install each valve in the port from which it was removed or to which it was fitted.
3. Install valve guide seal (intake valve only) over valve stem and push down until seated against head.
4. Set valve spring (with damper installed) and cap in place.
5. Place retainer on intake valve and/or rotator on exhaust valve.

6. While compressing valve spring with valve spring compressor, install oil seal in lower groove of valve stem, making sure seal is not twisted. A light coating of oil will help prevent twisting.



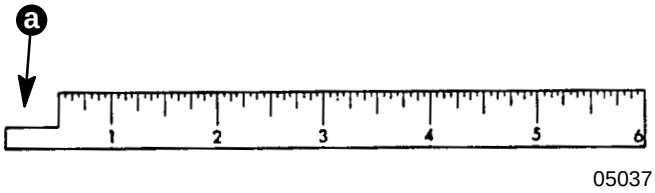
a - Valve Spring Compressor (J-8062)

7. Install valve locks (grease may be used to hold them in place) and slowly release tool, making sure locks seat properly in upper grooves of valve stem.

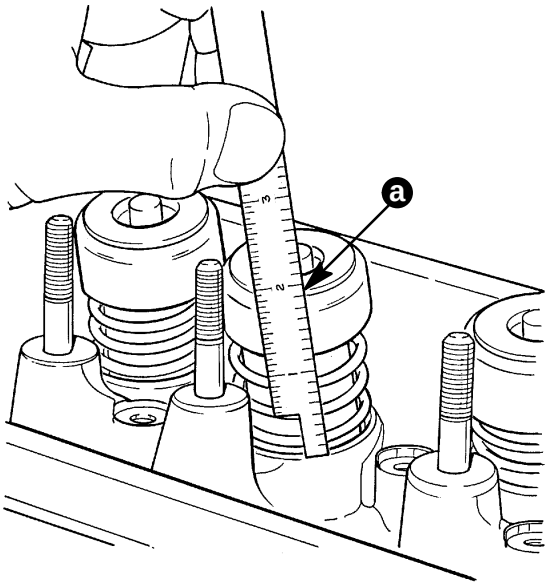


1 - Valve Locks
2 - Retainer
3 - Rotator
4 - Cap
5 - Valve Guide Oil Seal
6 - Valve Stem Oil Seal
7 - Damper
8 - Outer Spring
9 - Intake Valve
10 -Exhaust Valve

8. Check installed height of valve springs using a narrow, thin scale. Measure from spring seat to top of valve spring, as shown. If measurement exceeds specified height, install a valve spring shim and recheck. DO NOT shim valve springs to give an installed height less than the minimum specified.



a - Cut Out This Portion



a - Valve Spring Installed Height

Checking Valve Spring Installed Height

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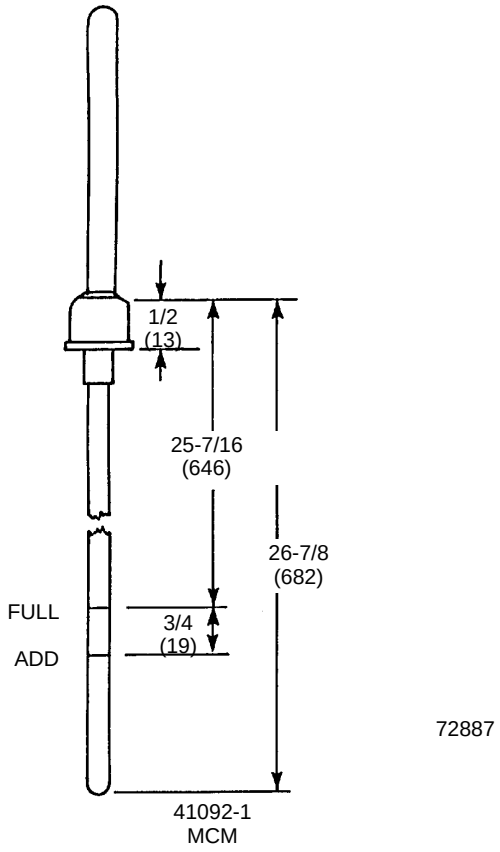
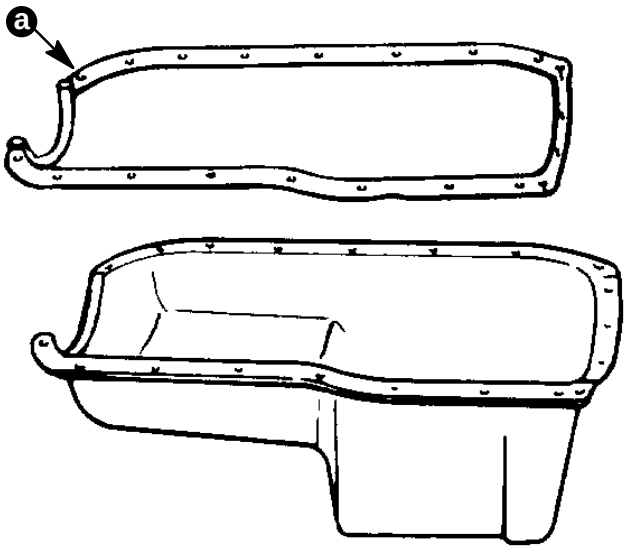
Dipstick Specifications

All Engines

UNIT OF MEASUREMENT In. (mm)



Oil Pan



a - 181 CID (3.0L) Engines - 1 piece oil pan gasket

Removal

1. Disconnect battery.

NOTE: *Removal of engine from boat may be required.*

2. Drain crankcase oil.
3. Remove starter motor.
4. Remove oil pan screws, oil pan, and gasket(s).

Installation

1. Clean sealing surfaces of engine block and oil pan.
2. Apply a small amount of Quicksilver RTV Sealer to joints of rear seal retainer and joints of front cover.

IMPORTANT: Quicksilver RTV Sealer sets up in about 15 minutes. Be sure to complete assembly promptly.

3. Install oil pan gasket in position as shown.

NOTE: *A one-piece oil pan gasket may be reused if it is still pliable and is not cracked, torn or otherwise damaged.*

4. Install oil pan. Starting from the center and working outward in each direction, tighten 1/4-20 threaded fasteners to 80 lb. in. (9 N·m) and 5/16-18 threaded fasteners to 165 lb. in. (19 N·m).
5. Install dipstick tube and dipstick.
6. Fill crankcase with required quantity of oil of specified viscosity. See Section 1B - "Maintenance."

Oil Pump

The oil pump consists of two gears and a pressure regulator valve enclosed in a two-piece housing. Oil pump is driven by distributor shaft which is driven by a helical gear on camshaft.

Removal

1. Remove oil pan as previously outlined.
2. Remove gasket carefully as the one-piece gasket for the oil pan may be reused if still pliable and not cracked, torn, etc.
3. Remove oil pump

Disassembly

1. Remove pump cover.

IMPORTANT: Mark gear teeth for reassembly with same teeth indexing.

2. Remove idler gear and drive gear from pump body.
3. Remove retaining pin, spring, and pressure regulator valve from pump cover.

IMPORTANT: Do not remove pickup screen and pipe assembly, unless replacement is necessary. Loss of press fit condition could result in an air leak and loss of oil pressure.

IMPORTANT: Do not disturb pickup screen on pipe. This is serviced as an assembly.

4. If pickup screen and pipe assembly requires replacement, mount pump in a soft-jawed vise and extract pipe from pump.

Cleaning and Inspection

1. Wash all parts in cleaning solvent and dry with compressed air.
2. Inspect pump body and cover for cracks or excessive wear.
3. Inspect pump gears for damage and excessive wear.
4. Check for loose drive gear shaft in pump body.
5. Inspect inside of pump cover for wear that would permit oil to leak past ends of gears.

IMPORTANT: Pump gears and body are not serviced separately. If pump gears or body are damaged or worn, replacement of entire oil pump assembly is necessary.

6. Inspect pickup screen and pipe assembly for damage to screen and pipe.
7. Check pressure regulator valve for fit.

Reassembly

⚠CAUTION

Be careful of twisting, shearing or collapsing pipe while installing in pump. Pickup screen must be parallel to oil pan bottom when oil pump is installed.

If pickup screen and pipe assembly was removed, mount pump in a soft-jawed vise, apply Quicksilver Perfect Seal to end of new pipe and, using oil pump suction pipe installer (J-21882), tap the pipe in place with a hammer.

IMPORTANT: Oil internal parts liberally before installation.

1. Install pressure regulator valve and related parts.
2. Install drive gear in pump body.
3. Install idler gear in pump body with smooth side of gear toward pump cover opening. Align marks made in disassembly.
4. Fill gear cavity with engine oil.

5. Install pump cover and torque attaching bolts to 80 lb. in. (9 N·m).
6. Turn extension shaft by hand to check for smooth operation.

Installation

1. Install pump, with extension shaft, to rear main bearing, aligning extension shaft with distributor drive shaft.
2. Tighten oil pump bolt to 65 lb. ft. (88 N·m).
3. Install oil pan as outlined. The one-piece gasket for the oil pan may be reused if still pliable and not cracked, torn, etc.

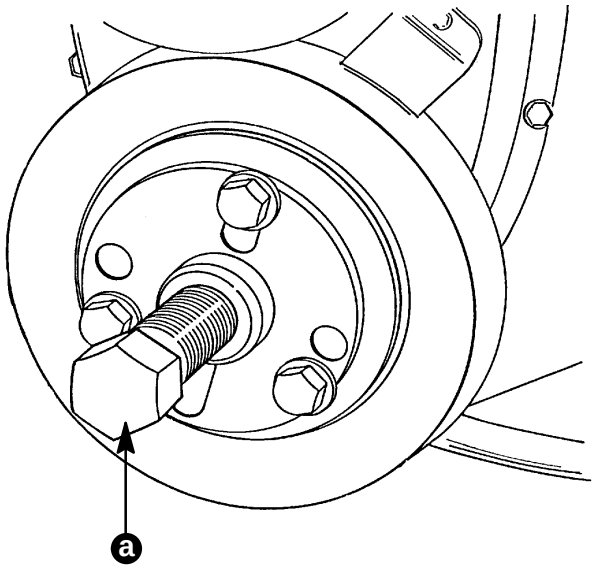
Torsional Damper

Removal

1. Support front of engine (if in boat) with overhead hoist.
2. Remove front mounting bracket and drive belt. (Remove retaining bolt, if so equipped.)
3. Install tool J-6978-E to balancer and turn puller Remove drive pulley, then remove torsional damper retaining bolt.

IMPORTANT: DO NOT use a universal claw type puller to remove torsional damper (in next step) as outside ring of torsional damper is bonded in rubber to the hub and use of claw type puller may break the bond.

4. Remove torsional damper with torsional damper remover and installer.



72890

a - Torsional Damper Remover and Installer (J-6978-E)

Installation

IMPORTANT: The inertia weight section of torsional damper is assembled to the hub with a rubber type material. The installation procedure (with proper tool) must be followed or movement of the inertia weight on the hub will destroy the tuning of the torsional damper.

1. Replace key in crankshaft if it is damaged.
2. Coat seal surface of torsional damper with engine oil.

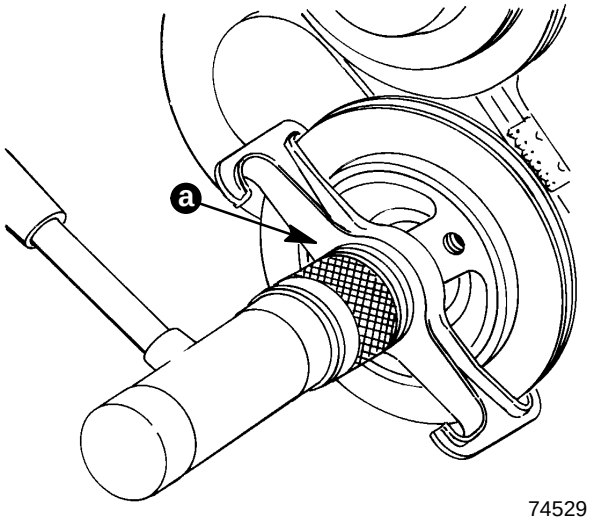
NOTE: *If a suitable torsional damper installer installation tool is not available, use a block of wood as a driver. Be very careful not to cause pulley or weight to shift on their rubber mounts.*

3. Install torsional damper on crankshaft, using torsional damper remover and installer as follows:
   a. Install appropriate end of threaded rod into crankshaft.

IMPORTANT: Be sure to install threaded rod in crankshaft at least 1/2 in. (13 mm) to prevent damage to threads.

   b. Install plate, thrust bearing, washer and nut on rod.

c. Install torsional damper on crankshaft by turning nut until it bottoms out.



a - Torsional Damper Remover and Installer (J-23523-E)

d. Remove tool from crankshaft.

e. To prevent oil leakage, apply Quicksilver RTV sealant to torsional damper keyway.

f. Install torsional damper bolt. Torque to 70 lb. ft. (95 N·m).

4. Install drive pulley(s). Torque bolts to 35 lb. ft. (48 N·m).
5. Install and adjust drive belts.

Crankcase Front Cover/ Oil Seal

Oil Seal Replacement (Without Removing Front Cover)

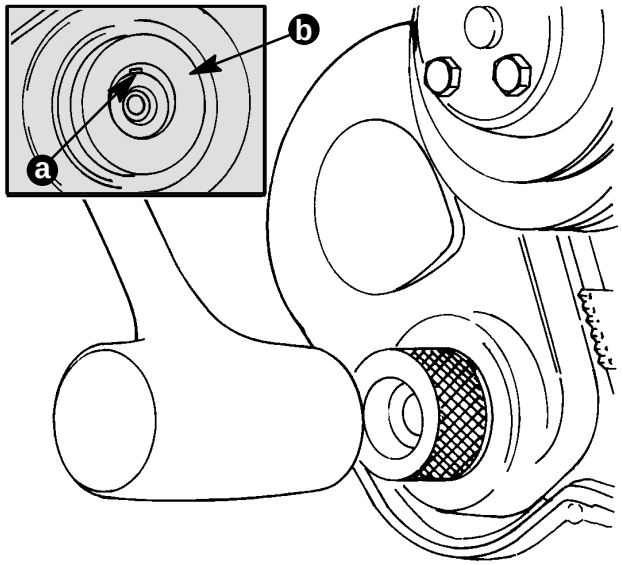
REMOVAL

1. Remove torsional damper.
2. Pry seal out of cover from the front with a large screwdriver, being careful not to distort front cover or damage crankshaft.

INSTALLATION

IMPORTANT: Correct rotation oil seal must be used to prevent oil leak.

1. Apply Quicksilver Perfect Seal to seal retainer mating surface and apply grease to seal lips.
2. Install new seal with open end of seal inward, using crankcase front cover seal installer. Drive seal in until it just bottoms out. Do not use excessive force.



a - Key In Crankshaft
b – Lobe of Bore Clears Key

3. Reinstall torsional damper as outlined.

Crankcase Front Cover

Removal

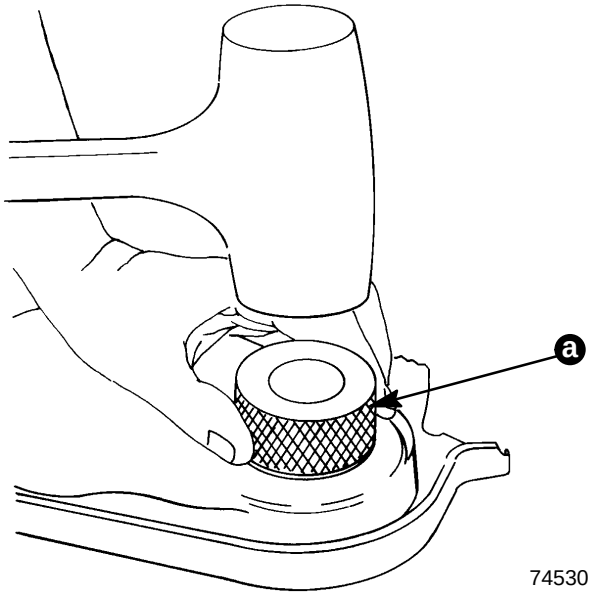
1. Remove engine from boat if necessary to gain access to cover.
2. Remove torsional damper and oil pan.
3. Remove water circulating pump.
4. Remove crankcase front cover.
5. If damaged, drive oil seal out of front cover (from the rear) using a punch.

Cleaning and Inspection

Clean front cover in solvent and dry with compressed air. Clean old gasket material and sealer from mating surfaces on cover and cylinder block. Check gasket surface on front cover for distortion, and true if necessary. Surfaces must be clean and flat or oil leakage may result.

Installation

1. Install oil seal in cover with lip of seal toward inside of engine, using crankcase front cover seal installer. Support cover around seal area with appropriate tool as shown.



74530

a - Crankcase Front Cover Seal Installer (J-35468)

2. Coat both sides of front cover gasket with Quicksilver Perfect Seal and place in position on engine.
3. Install front cover, making sure holes in cover align with dowel pins in block. Torque front cover attaching screws to 100 lb. in. (11 N·m).
4. Install oil pan and torsional damper as outlined.
5. Install water circulating pump.
6. Reinstall engine in boat.
7. Fill crankcase with engine oil.

⚠CAUTION

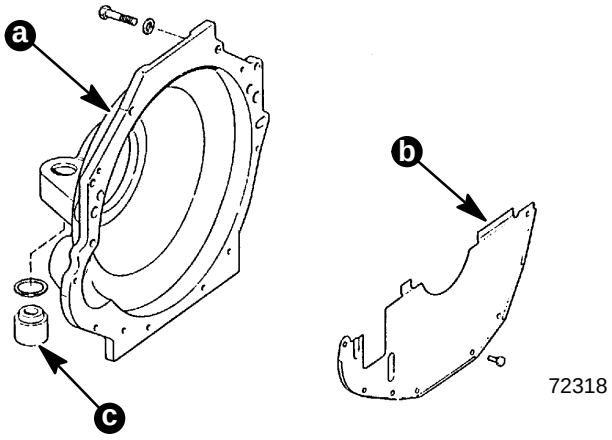
Ensure that cooling water supply is available before starting the engine.

8. Start engine and check for water and oil leaks.

Flywheel and Engine Coupler

Removal

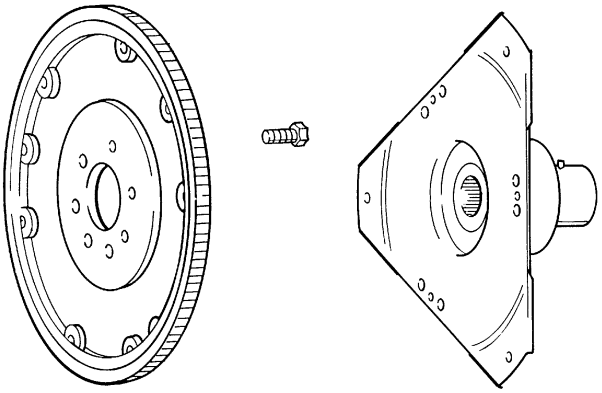
1. Remove engine from boat. Refer to SECTION 2 - “Removal and Installation”.
2. Refer to “Flywheel Housing” description in this section and remove flywheel housing and related parts.



72318

a - Flywheel Housing
b - Cover
c - Press Mount Out with Press

3. Remove MCM coupler.
4. Remove flywheel.



72349

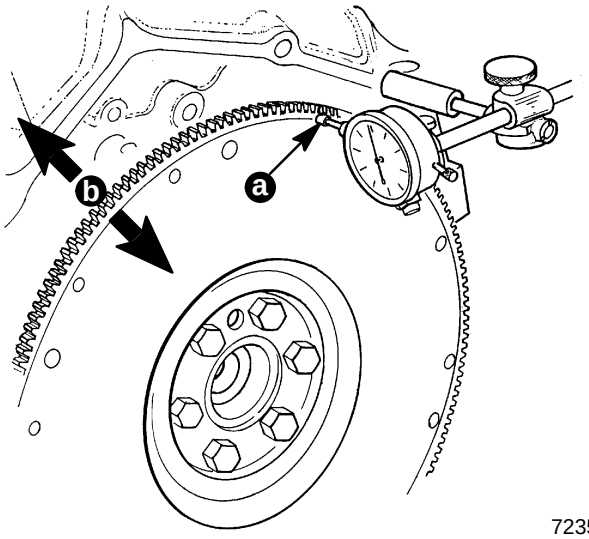
Alpha One Coupler

Inspection

1. Inspect splines in coupler for wear.
2. Check flywheel ring gear for worn and missing teeth.

Installation

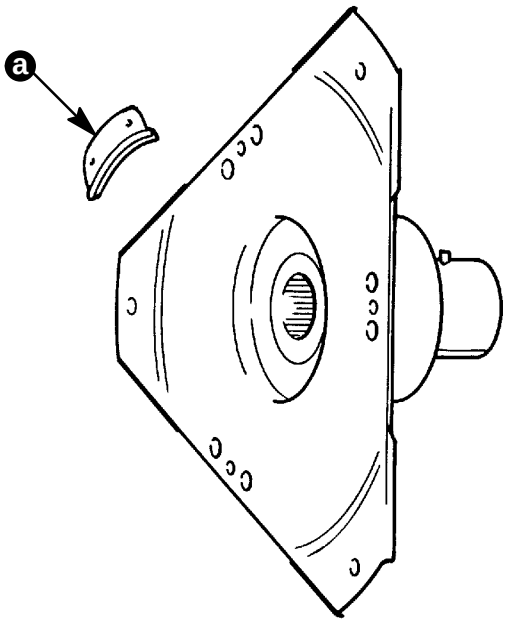
1. Clean mating surfaces of flywheel and crankshaft. Remove any burrs. Mating surfaces must be clean bare metal.
2. Aligning dowel hole in flywheel with dowel in crankshaft, install flywheel. Torque bolts to 75 lb. ft. (100 N·m).
3. Check flywheel runout as follows:
   a. Attach a dial indicator to engine block.
   b. Take readings around outer edge of flywheel. Push in on flywheel to remove crankshaft end play.
   c. Maximum runout - .008 in. (0.203 mm).



72353

a - .008 in. (0.203 mm) Max. Runout
b - Push Flywheel and Crankshaft Forward as Far as It Will Go when Taking Reading

4. Insert three rubber bumpers in Alpha coupler before installation on flywheel.



72354

a - Rubber Bumper

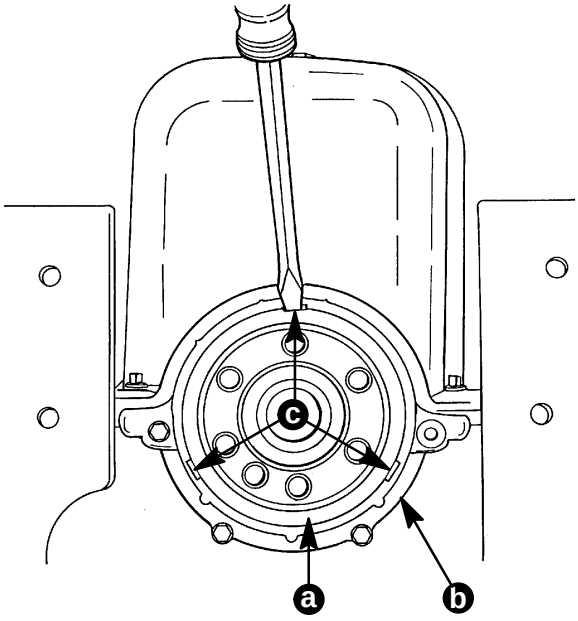
5. Install drive coupler. Torque bolts to 35 lb. ft. (48 N·m). If reusing screws, use Loctite 8831.
6. Install flywheel housing and related parts. Torque bolts to 30 lb. ft. (41 N·m).
7. Install flywheel housing cover. Torque bolts to 80 lb. in. (9 N·m).
8. Refer to SECTION 2 “Removal and Installation” and install engine.

Rear Main Oil Seal

The rear crankshaft oil seal can be replaced without removing the oil pan or rear main bearing cap from engine.

Removal

Remove seal by using a screwdriver to pry it out of retainer as shown.



72355

a - Rear Seal
b - Seal Retainer
c - Slots (Three)

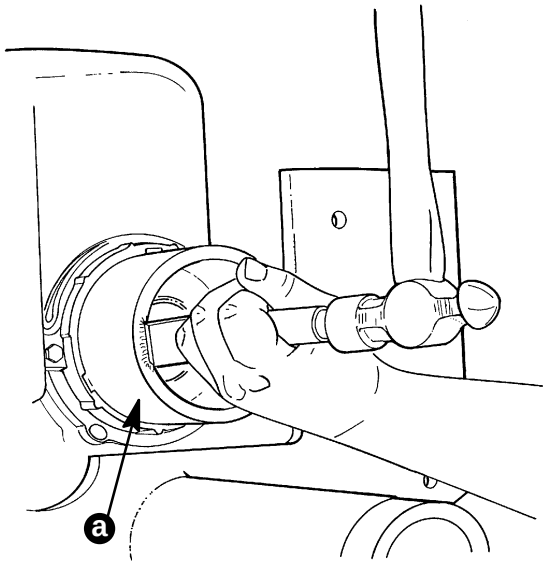
Cleaning and Inspection

Clean crankshaft/seal running surface and seal retainer.

IMPORTANT: Correct rotation oil seal must be used to prevent oil leak.

Installation

1. Apply Quicksilver Perfect Seal to seal retainer mating surface. Apply grease to seal lips.
2. Install seal using rear main seal installer.



72356

a - Rear Main Seal Installer (J-26817-A)

Cleaning and Inspection

1. Clean gasket material from mating surfaces.
2. Inspect oil seal retainer for cracks or scored surface.
3. Inspect oil seal for worn, dry or torn rubber. Replace if necessary (refer to “Rear Main Oil Seal” as outlined).
4. Inspect alignment pin for damage; replace if necessary.

Installation

1. Coat seal lips with clean motor oil.
2. Install gasket and oil seal retainer with rear main seal.
3. Coat threads of oil seal retainer fasteners with Loctite Pipe Sealant with Teflon.
4. Install fasteners and torque to 133 lb. in. (15 N·m).
5. Install oil pan fasteners. Torque 1/4-20 threaded fasteners to 80 lb. in. (9 N·m) and 5/16-18 threaded fasteners to 165 lb. in. (19 N·m).

NOTE: *A one-piece oil pan gasket may be re-used if it is still pliable and is not cracked, torn or otherwise damaged.*

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Main Bearings

IMPORTANT: Before removing main bearing caps or connecting rod caps, mark them for reassembly in their original locations.

Main bearings are of the precision insert type and do not use shims for adjustment. If clearances are found to be excessive, a new bearing, both upper and lower halves, will be required. Service bearings are available in standard size and .001 in., .010 in. and .020 in. undersize.

Selective fitting of both rod and main bearing inserts is necessary in production in order to obtain close tolerances. For this reason you may find one half of a standard insert with one half of a .001 in. undersize insert which will decrease the clearance .0005 in. from using a full standard bearing.

When a production crankshaft cannot be precision fitted by this method, it then is ground .009 in. undersize on main journals only. A .009 in undersize bearing and .010 in. undersize bearing may be used for precision fitting in same manner as previously described. Any engine, fitted with a .009 in. undersize crankshaft, will be identified by the following markings:

- ".009" will be stamped on crankshaft counterweight forward of center main journal.
- No. "9" will be stamped on block at left front oil pan rail.

IMPORTANT: If crankshaft has an undersize journal and a new bearing is required, journal must be reconditioned to accept a .010 or .020 in. undersize bearing as .009 in. undersize bearings are not available for service.

Inspection

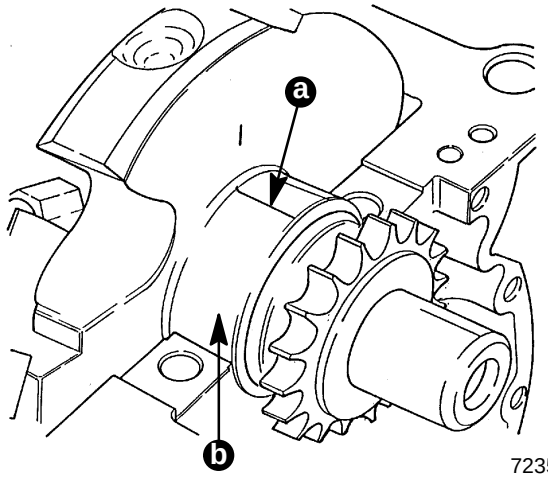
In general, the lower half of the bearing (except No. 1 bearing) shows a greater wear and the most distress from fatigue. If, upon inspection, the lower half is suitable for use, it can be assumed that the upper half is also satisfactory. If the lower half shows evidence of wear or damage, both upper and lower halves should be replaced. Never replace one half without replacing the other half.

Checking Clearances

To obtain accurate measurements while using Plastigage, or its equivalent, engine must be out of the boat and upside down so crankshaft will rest on the upper bearings and total clearance can be measured between lower bearing and journal.

To assure the proper seating of the crankshaft, all bearing cap bolts should be at their specified torque. In addition, preparatory to checking fit of bearings, the surface of the crankshaft journal and bearing should be wiped clean of oil.

1. With the oil pan and oil pump removed, remove bearing cap and wipe oil from journal and bearing cap to be inspected.
2. Place a piece of gauging plastic the full width of the bearing (parallel to the crankshaft) on the journal as shown.



72357

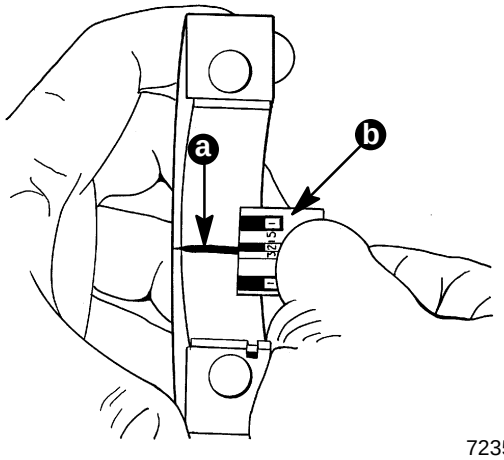
a - Gauging Plastic
b - Journal

3. Install the bearing cap and evenly torque the retaining bolts to specifications. Bearing cap MUST be torqued to specification in order to assure proper reading. Variations in torque affect the compression of the plastic gauge.

IMPORTANT: Do not rotate the crankshaft while the gauging plastic is between the bearing and journal.

4. Remove bearing cap. The flattened gauging plastic will be found adhering to either the bearing cap or journal.

5. On the edge of the gauging plastic envelope there is a graduated scale which is correlated in thousandths of an inch. Without removing the gauging plastic, measure its compressed width (at the widest point) with the graduations on the gauging plastic envelope as shown.



72358

a - Compressed Gauging Plastic
b - Graduated Scale

NOTE: *Normally main bearing journals wear evenly and are not out of round. However, if a bearing is being fitted to an out-of-round journal (.001 in. max.), be sure to fit to the maximum diameter of the journal: If the bearing is fitted to the minimum diameter, and the journal is out of round .001 in., interference between the bearing and journal will result in rapid bearing failure. If the flattened gauging plastic tapers toward the middle or ends, there is a difference in clearance indicating taper, low spot or other irregularity of the bearing or journal. Be sure to measure the journal with a micrometer if the flattened gauging plastic indicates more than .001 in. difference.*

6. If the bearing clearance is within specifications, the bearing insert is satisfactory. If the clearance is not within specifications, replace the insert. Always replace both upper and lower inserts as a unit.
7. A standard, or .001 in., undersize bearing may produce the proper clearance. If not, it will be necessary to regrind the crankshaft journal for use with the next undersize bearing.
8. After selecting new bearing, recheck clearance.
9. Proceed to the next bearing. After all bearings have been checked, rotate the crankshaft to see that there is no excessive drag. When checking No. 1 main bearing, loosen accessory drive belts so as to prevent tapered reading with plastic gauge.

Main Bearing Replacement

1. Remove and inspect crankshaft.
2. Remove main bearings from cylinder block and main bearing caps.
3. Coat bearing surfaces of new, correct-size, main bearing with oil and install in cylinder block and main bearing caps. Check clearance.
4. Install crankshaft.
5. Torque all main bearing caps, EXCEPT THE REAR MAIN CAP, to 75 lb. ft. (102 N·m). Torque rear main bearing cap to 10-12 lb. ft. (14-16 N·m); then tap end of crankshaft, first rearward then forward with a lead hammer. This will line up rear main bearing and crankshaft thrust surfaces. Torque rear main bearing cap to 75 lb. ft. (102 N·m).

Connecting Rod Bearings

Connecting rod bearings are of the precision insert type and do not use shims for adjustment. DO NOT FILE RODS OR ROD CAPS. If clearances are found to be excessive, a new bearing will be required. Service bearings are available in standard size and .001 in. and .002 in. undersize for use with new and used standard size crankshafts, and in .010 in. and .020 in. undersize for use with reconditioned crankshafts.

On removing a connecting rod cap, it is possible to find a .010 in. undersize bearing. These are used in manufacturing for selective fitting.

Inspection and Replacement

IMPORTANT: Before you remove the connecting rod cap, mark the side of the rod and cap with the cylinder number to assure matched reassembly of rod and cap.

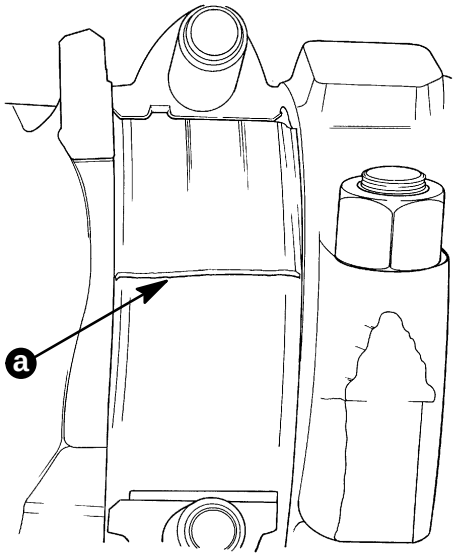
1. Remove connecting rod cap and bearing.
2. Inspect bearing for evidence of wear or damage. (Defective bearings should not be installed) Typical bearing failures are shown under ”General”.
3. Wipe bearings and crankshaft clean of oil.
4. Measure crankpin for out-of-round of taper with a micrometer. If not within specifications, replace or recondition crankshaft. If within specifications and new bearing is to be installed, measure maximum diameter of crankpin to determine new bearing size required.
5. If within specifications, measure new or used bearing clearances with Plastigage or equivalent.

IMPORTANT: If bearing is fitted to out-of-round crankpin, br sure to fit maximum diameter of crankpin. If bearing is fitted to minimum diameter, and crankpin is out-of-round .001 (0.025mm), interference between bearing and crankpin will result in rapid bearing failure.

a. Place a piece of guaging plastic the full width of crankpin (parallel to crankshaft).

b. Install bearing connecting rod and cap.

c. Place a piece of gauging plastic, the length of the bearing (parallel to the crankshaft), on the crankpin or bearing surface as shown. Position the gauging plastic in the middle of the bearing shell. (Bearings are eccentric and false readings could occur if placed elsewhere.)



72361

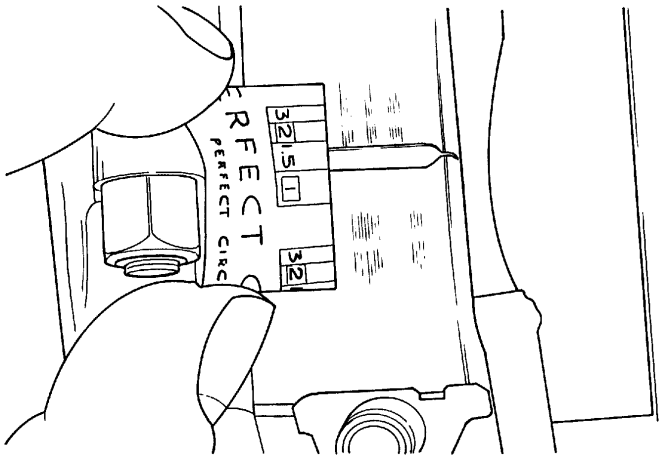
a - Gauging Plastic

d. Install the bearing in the connecting rod and cap.

e. Install the bearing cap and evenly torque nuts to 45 lb. ft. (61 N·m).

IMPORTANT: Do not turn the crankshaft with the gauging plastic installed.

f. Remove the bearing cap and using the scale on the gauging plastic envelope, measure the gauging plastic width at the widest point as shown.



72362

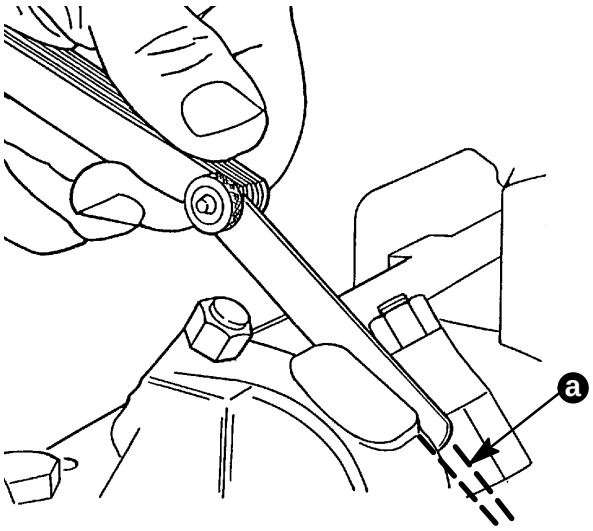
6. If the clearance exceeds specifications, select a new, correct size bearing and measure the clearance.

   Be sure to check what size bearing is being removed in order to determine proper replacement size bearing. If clearance cannot be brought to within specifications, the crankpin will have to be ground undersize. If the crankpin is already at maximum undersize, replace crankshaft.

7. Coat the bearing surface with oil, install the rod cap and torque nuts to 45 lb. ft. (61 N·m).

8. When all connecting rod bearings have been installed, tap each rod lightly (parallel to the crankpin) to make sure they have clearance.

9. Measure all connecting rod side clearances between connecting rod caps as shown - .006-.014 (0.152-0.356).



72891

a - Take Measurement Here

Connecting Rod/Piston Assembly

Removal

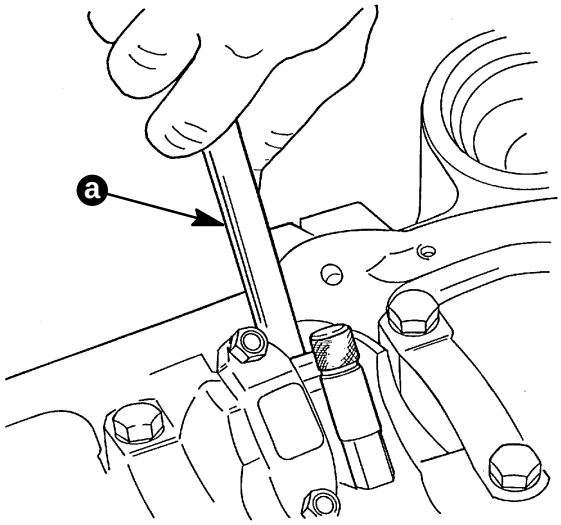
1. With oil, pan oil pump and cylinder head removed, use a ridge reamer to remove any ridge and/or deposits from upper end of cylinder bore

IMPORTANT: Before ridge and/or deposits are removed, turn crankshaft until piston is at bottom of stroke and place a cloth on top of piston to collect cuttings. After ridge and/or deposits are removed, turn crankshaft until piston is at top of stroke, then remove cloth and cuttings.

2. Inspect and mark connecting rods and bearing caps.

3. Remove connecting rod cap and install connecting rod bolt guide (3/8-24) on bolts. Push connecting rod and piston assembly out of top of cylinder block.

NOTE: *It will be necessary to turn crankshaft slightly to disconnect and remove some connecting rod and piston assemblies.*

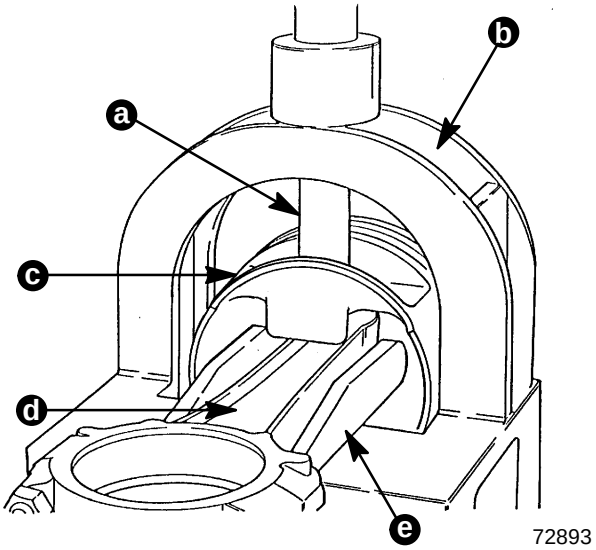


72892

a - Connecting Rod Bolt Guide (3/8-24) (J-5239)

Disassembly

1. Disassemble piston from connecting rod using piston pin remover as shown.



72893

a - Piston Pin Remover (J-24086-B)
b - Arched Base
c - Piston
d - Connecting Rod
e - Rod Support

2. Position connecting rod on tool rod support with rod support inserted between connecting rod end and piston. Align piston pin with hole located in top of arched base.
3. Insert pin remover thru hole (located in top of arched base) and into piston pin hole. Press on pin remover to remove piston pin.

Cleaning and Inspection

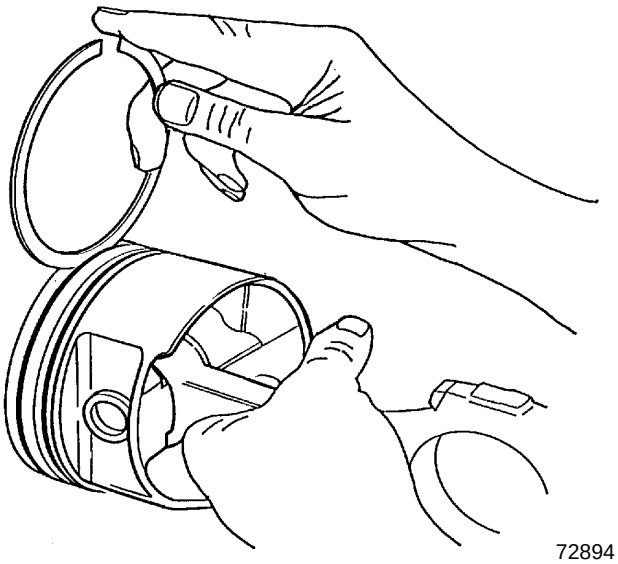
CONNECTING RODS

4. Wash connecting rods in cleaning solvent and dry with compressed air.
5. Check for twisted and bent rods and inspect for nicks and cracks. Replace damaged connecting rods.

PISTONS

NOTE: *Cylinder bore and taper must be within specifications before pistons can be considered for re-use.*

1. Clean varnish from piston skirts with a cleaning solvent. DO NOT WIRE BRUSH ANY PART OF PISTON. Clean ring grooves with a groove cleaner and make sure oil ring holes are clean.
2. Inspect piston for cracked ring lands, skirts and pin bosses, wavy worn ring lands, scuffed or damaged skirts, and eroded areas at top of piston. Replace pistons which are damaged or show signs of excessive wear.
3. Inspect grooves for nicks and burrs that might cause rings to hang up.
4. Measure piston skirt (across centerline of piston pin) and check clearance as outlined under “Cylinder Block”
5. Slip outer surface of a new top and second compression ring into respective piston ring groove and roll ring entirely around the groove to make sure that ring is free as shown. If binding occurs at any point, determine cause. If caused by ring groove, remove by dressing with a fine cut file. If binding is caused by a distorted ring, recheck with another ring.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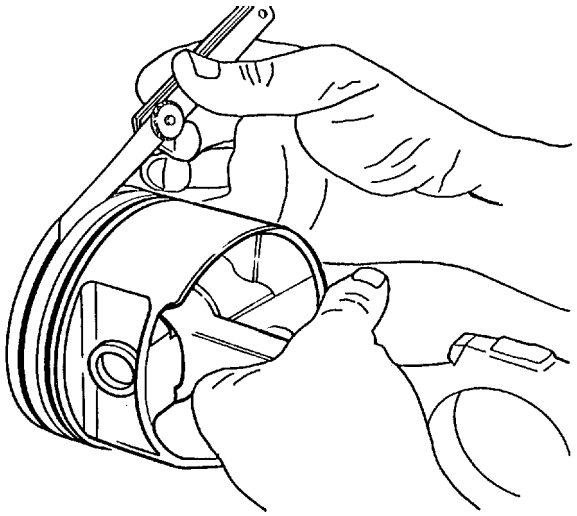
6. Proper clearance of piston ring in its piston ring groove is very important to provide proper ring action and reduce wear. Therefore, when fitting new rings, clearances between ring and groove surfaces should be measured. See “Specifications.”



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PISTON PINS

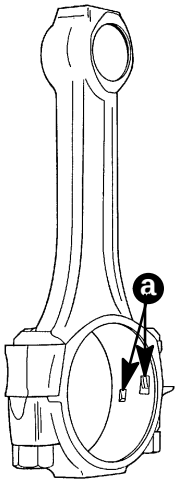
1. Piston pin clearance is designed to maintain adequate clearance under all engine operating conditions. Because of this, piston and piston pin are a matched set and not serviced separately.
2. Inspect piston pin bores and piston pins for wear. Piston pin bores and piston pins must be free of varnish and scuffing when measured. Measure piston pin with a micrometer and piston pin bore with a dial bore gauge or inside micrometer. If clearance is in excess of the .001 in. (0.025 mm) wear limit, replace piston and piston pin assembly.

Reassembly

PISTONS AND PISTON PINS

IMPORTANT: When reassembling pistons and connecting rods, the following must be kept in mind.

- **Piston and pin are machine fitted to each other and must remain together as a matched set. Do not intermix pistons and pins.**
- **If original pistons and/or connecting rods are being used, be sure to assemble pistons and connecting rods so they can be reinstalled in same cylinder from which they were removed.**
- **Connecting rod bearing tangs are always toward outside of cylinder block.**



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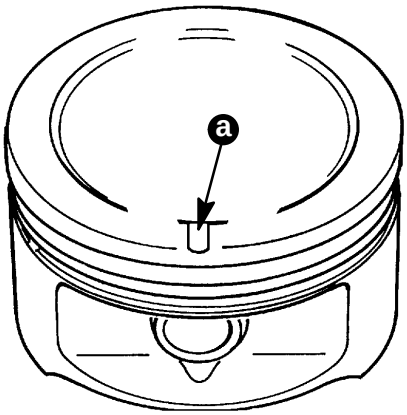
a - Rod Bearing Tangs

- **Notch on piston must be positioned toward the front of the engine.**



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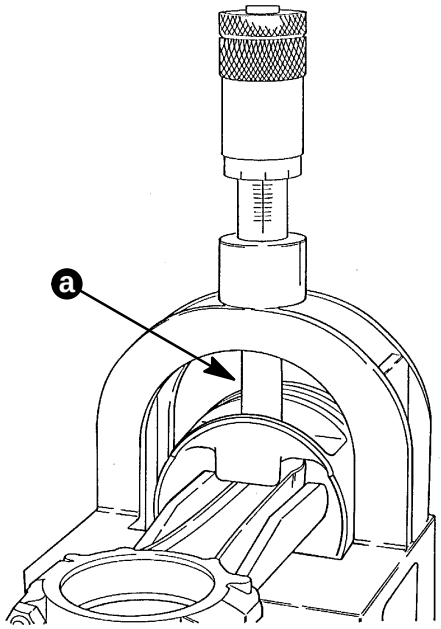
a - Notch

1. Assemble piston to connecting rod using piston pin remover as shown. Follow instructions supplied with kit.



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a - Piston Pin Remover (J-24086-B)

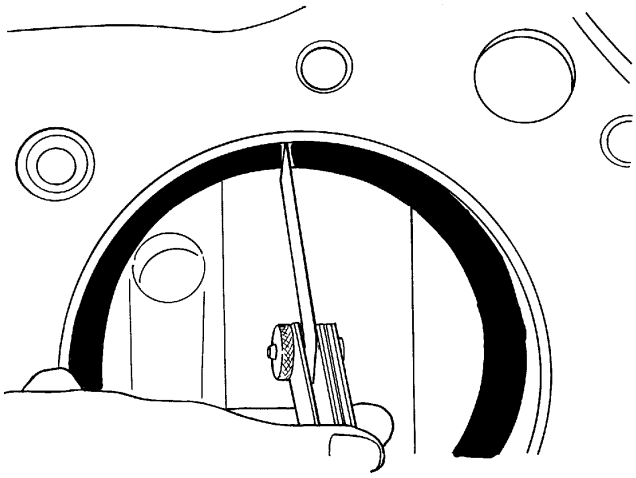
2. Once assembled, check piston for freedom of movement (back-and-forth and up-and-down) on connecting rod. Piston should move freely in all directions. If it does not, piston pin bore is tight and piston/pin assembly must be replaced.
3. If a new connecting rod has been installed, mark connecting rod and cap (on side of rod and cap with slots for connecting rod bearing tangs) with cylinder number in which it will be installed.

PISTON RINGS

All compression rings are marked on upper side of ring. When installing compression rings, make sure that marked side is toward top of piston. The top ring is treated with molybdenum for maximum life. Oil control rings are a three piece type, consisting of 2 segments (rails) and a spacer.

Oil control rings are a three-piece type, consisting of two rings and a spacer.

4. Select rings comparable in size to cylinder bore and piston size.
1. Slip compression ring in cylinder bore, then press ring down into cylinder bore about 1/4 in. (6 mm) (below ring travel). Be sure that ring is square with cylinder wall.
2. Measure gap between ends of ring with a feeler gauge as shown.



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3. If gap between ends of ring is below specifications, remove ring and try another for fit.
4. Fit each compression ring to cylinder in which it is going to be used.
5. Clean and inspect pistons, if not previously done.
6. Install piston rings as follows:
   a. Install oil ring spacer in groove and insert anti-rotation tang in oil hole.
   b. Hold spacer ends butted and install lower steel oil ring rail with gap properly located.
   c. Install upper steel oil ring rail with gap properly located.
   d. Flex the oil ring assembly to make sure ring is free. If binding occurs at any point, the cause should be determined and, if caused by ring groove, removed by dressing groove with a fine cut file. If binding is caused by a distorted ring, use a new ring.

IMPORTANT: Use piston ring expander (91-24697) for compression ring installation.

   e. Install lower compression ring with marked side up, using ring expander.

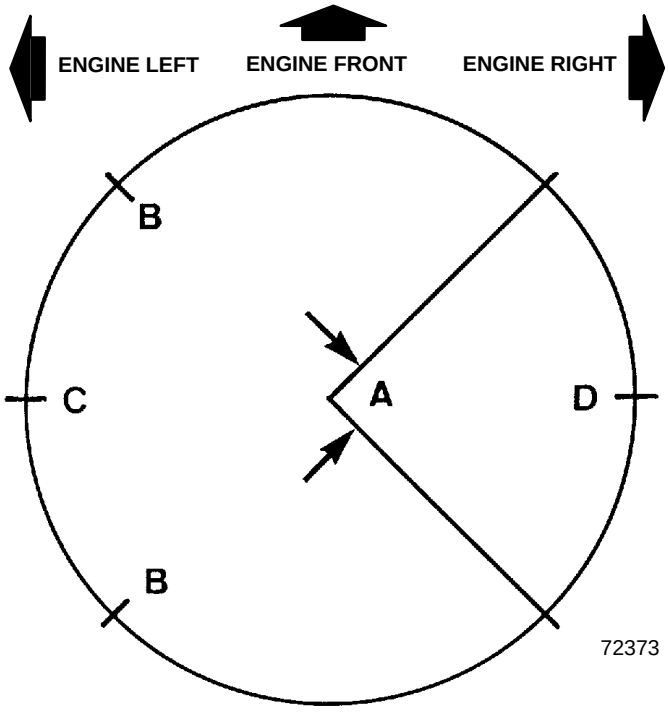
f. Install top compression ring with marked side up, using ring expander.

Installation

IMPORTANT: Cylinder bores must be clean before piston installation. Clean with a light honing, as necessary. Then clean with hot water and detergent wash. After cleaning, swab bores several times with light engine oil and clean cloth, then wipe with a clean dry cloth.

1. Lubricate connecting rod bearings and install in rods and rod caps.
2. Lightly coat pistons, rings and cylinder walls with light engine oil.
3. With bearing caps removed, install connecting rod bolt guide (3/8-24) (J-5239) on connecting rod bolts.

IMPORTANT: Be sure ring gaps are properly positioned as shown.

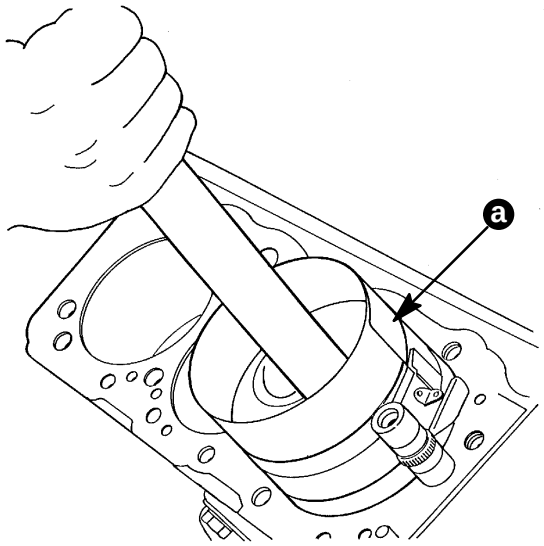


A - Oil Ring Spacer Gap (Tang in Hole or Slot within Arc)
B - Oil Ring Rail Gaps
C - 2nd Compression Ring Gap
D - Top Compression Ring Gap

Ring Gap Location

4. Install each connecting rod and piston assembly in its respective bore. Install with connecting rod bearing tangs toward outside of cylinder block. Use piston ring compressor to compress rings. Guide connecting rod into place on crankshaft journal with connecting rod bolt guide. Use a hammer handle with light blows to install piston into bore. Hold ring compressor firmly against cylinder block until all piston rings have entered cylinder bore.

IMPORTANT: Be sure to install new pistons in same cylinders for which they were fitted, and used pistons in same cylinder from which they were removed. Each connecting rod and bearing cap should be marked, beginning at front of engine. Numbers on connecting rod and bearing cap must be on same side when installed in cylinder bore. If a connecting rod is ever transposed from one block or cylinder to another, new bearings should be fitted and connecting rod should be numbered to correspond with new cylinder number.



a - Piston Ring Compressor (J-8037)

5. Remove connecting rod bolt guide.
6. Install bearing caps and torque nuts to 20 lb. ft. (27 N·m), then tighten nuts an additional 60 degrees angular torque using a Torque Angle Gauge.
7. Check connecting rod side clearance as previously described.

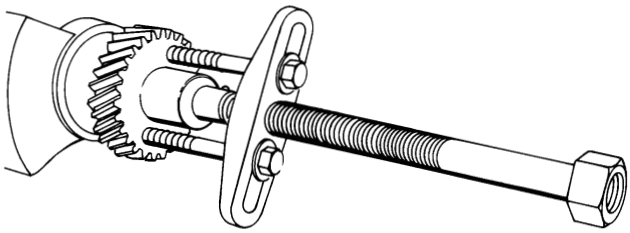
NOTE: *If bearing replacement is required, refer to "Connecting Rod Bearings."*

8. Install as previously outlined:
   a. Oil pump.
   b. Dipstick and oil pan.
   c. Cylinder heads.
   d. Intake manifold.
   e. Distributor.
9. Fill crankcase with oil. Refer to SECTION 1 - “Maintenance.”
10. Torque rocker arm nuts to 20 lb. ft. (27 N·m).

Crankshaft

Removal

1. Remove engine from boat.
2. Drain crankcase oil.
3. Remove as outlined:
   a. Starter.
   b. Flywheel housing.
   c. Drive coupler and flywheel.
   d. Belts.
   e. Water pump.
   f. Crankshaft pulley and torsional damper.
   g. Spark plugs.
   h. Oil pan and dipstick tube.
   i. Oil pump.
   j. Timing chain cover.
4. Turn crankshaft to align timing mark with camshaft mark.
5. Remove camshaft sprocket.
6. Remove rear main seal and retainer.
7. Ensure all bearing caps (main and connecting rods) are marked so they can be reinstalled in their original locations.
8. Remove connecting rod bearing caps, then push piston and rod assemblies toward heads.
9. Remove main bearing caps and carefully lift crankshaft out of cylinder block.
10. Remove crankshaft gear as shown.



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11. If new main and/or connecting rod bearings are to be installed, remove main bearing inserts from cylinder block and bearing caps, and/or connecting rod bearing inserts from connecting rod and caps. Install new bearings following procedures outlined.

Cleaning and Inspection

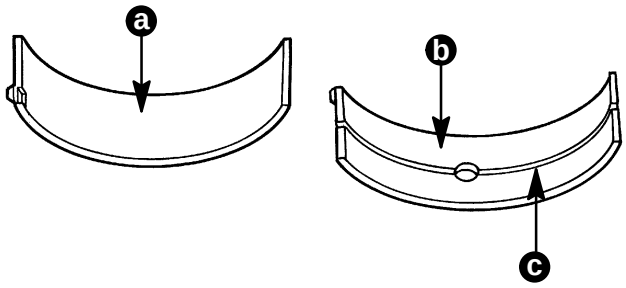
1. Wash crankshaft in solvent and dry with compressed air.
2. Measure main bearing journals and crankpin dimensions with a micrometer for out-of-round, taper or undersize (see “Specifications”).
3. Check crankshaft for runout (by supporting at front and rear main bearings journals in V-blocks) and check at front and rear intermediate journals with a dial indicator (see “Specifications”).
4. Replace or recondition crankshaft if not within specifications.

Installation

1. If a new crankshaft is being installed, remove timing sprocket from old crankshaft and reinstall on new crankshaft as outlined.

IMPORTANT: Be sure that all bearings and crankshaft journals are clean.

2. Install main bearings in engine block as shown.



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a - Lower Bearing Insert
b - Upper Bearing Insert
c - Oil Groove

Main Bearing Inserts

1. Carefully lower crankshaft into place. Be careful not to damage bearing surface.
2. Check clearance of each main bearing, following procedure outlined under “Main Bearings.” If bearing clearances are satisfactory, apply engine oil to journals and bearings.
3. Install main bearing caps. Torque bolts to 75 lb. ft. (102 N·m). When tightening rear main bearing cap, follow procedure outlined under “Main Bearings.”
4. Check crankshaft end play as previously outlined.
5. Install rear main seal retainer and seal. Torque fasteners to 133 lb. in. (15 N·m).
6. Check clearance for each connecting rod bearing, following procedure under “Connecting Rod Bearings.” If bearing clearances are satisfactory, apply engine oil to journals and bearings.
7. Install rod caps and torque nuts to 45 lb. ft. (61 N·m).
8. Turn crankshaft so mark on timing sprocket is facing camshaft.
9. Install as outlined:
   a. Timing chain and sprocket on camshaft - align marks with crankshaft.
   b. Timing chain cover.
   c. Oil pump.
   d. Dipstick tube and oil pan.
   e. Spark plugs.
   f. Torsional damper and crankshaft pulley.
   g. Water pump.
   h. Belts.
   i. Flywheel and drive coupler.
   j. Flywheel housing.
   k. Starter.
10. Install new oil filter. Fill crankcase with oil.

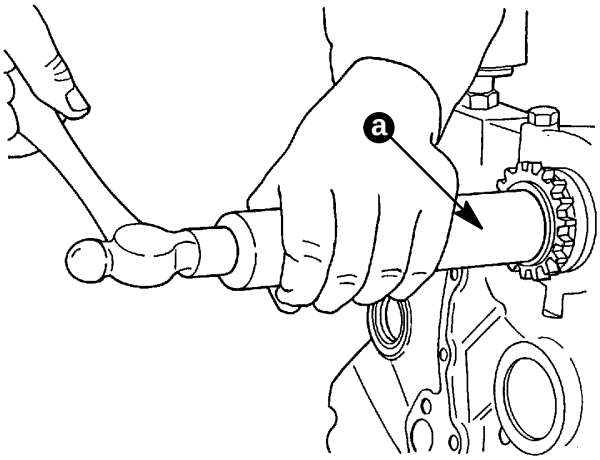
Crankshaft Sprocket

Removal

1. Remove torsional damper and crankcase front cover as previously outlined.
2. Remove camshaft timing chain as outlined, and using crankshaft gear and sprocket puller (J-5825-A), remove crankshaft sprocket.

Installation

1. Using crankshaft gear and sprocket installer, as shown, install sprocket on crankshaft.



72377

a - Crankshaft Gear and Sprocket Installer (J-5590)

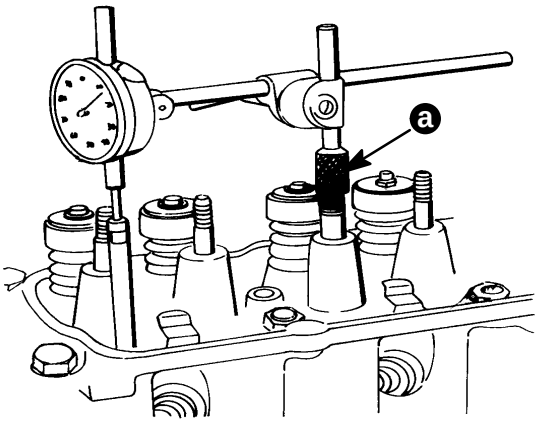
2. Install timing chain as outlined.
3. Install crankcase cover and torsional damper as outlined.

Camshaft

Measuring Lobe Lift

NOTE: *Procedure is similar to checking valve timing. If improper valve operation is indicated, measure lift of each push rod in consecutive order and record readings.*

4. Remove valve mechanism as previously outlined.
5. Position indicator with ball socket adaptor tool on push rod. Be sure that push rod is in lifter socket.



72907

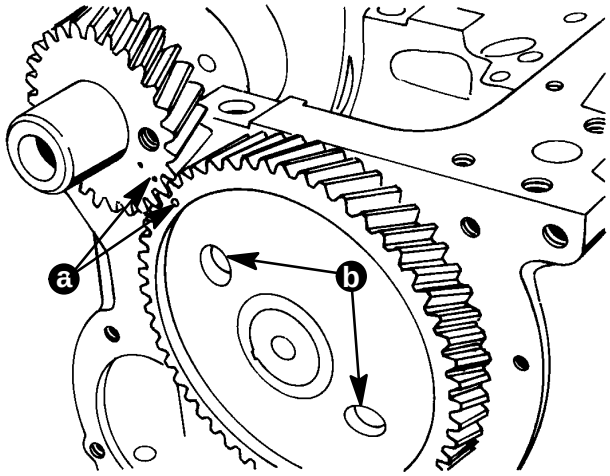
a - Ball Socket Adaptor Tool (J-8520-1)

6. Rotate crankshaft torsional damper slowly in direction of rotation until lifter is on heel of cam lobe. At this point, push rod will be in its lowest position.
7. Set dial indicator on zero, then rotate balancer slowly (or attach an auxiliary starter switch and “bump” engine over) until push rod is in fully raised position.
8. Compare total lift, recorded from dial indicator, with “Specifications.”
9. Continue to rotate engine until indicator reads zero. This will be a check on accuracy of original indicator reading.
10. If camshaft readings for all lobes are within specifications, remove dial indicator assembly.
11. Install rocker arm and push rod. Torque nuts to 20 lb. ft. (27 N·m).

Removal

1. Remove valve lifters as previously outlined.
2. Remove crankcase front cover as previously outlined.
3. Remove fuel pump.
4. Align timing gear marks, then remove the two camshaft thrust plate screws by working thru holes in camshaft gear.
5. Pull camshaft and gear assembly out thru front of block.

IMPORTANT: Support camshaft carefully when removing to protect camshaft bearings.

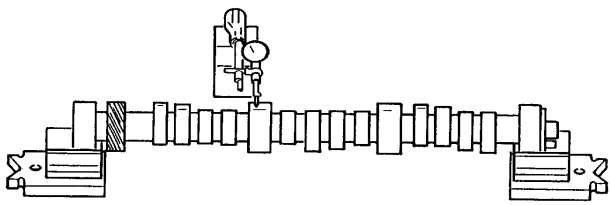


74438

a - Timing Marks
b - Screw Access Holes

Inspection

1. Measure camshaft bearing journals with a micrometer for out-of-round condition. If journals exceed .001 in. (0.025 mm) out-of-round, camshaft should be replaced.
2. Also check camshaft for alignment with V-blocks and dial indicator which indicates exact amount camshaft is out of true. If dial indicator reads more than .002 in. (0.051 mm) camshaft should be replaced.



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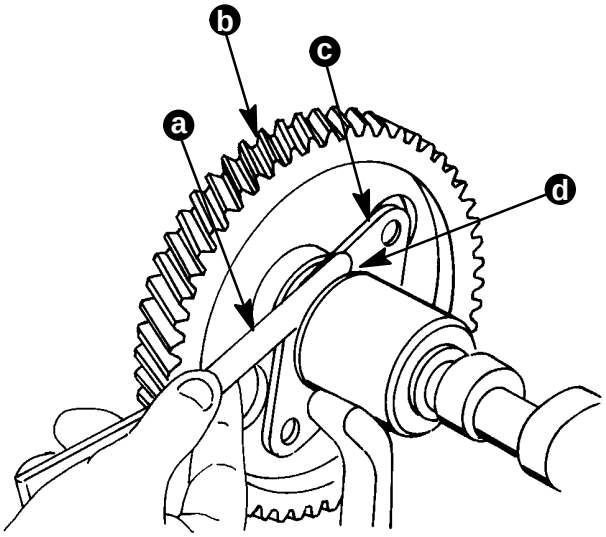
Checking Camshaft Alignment

3. Inspect camshaft gear and thrust plate for wear or damage. Measure camshaft end play .001 - .005 in. (0.03-0.1 mm)



74439

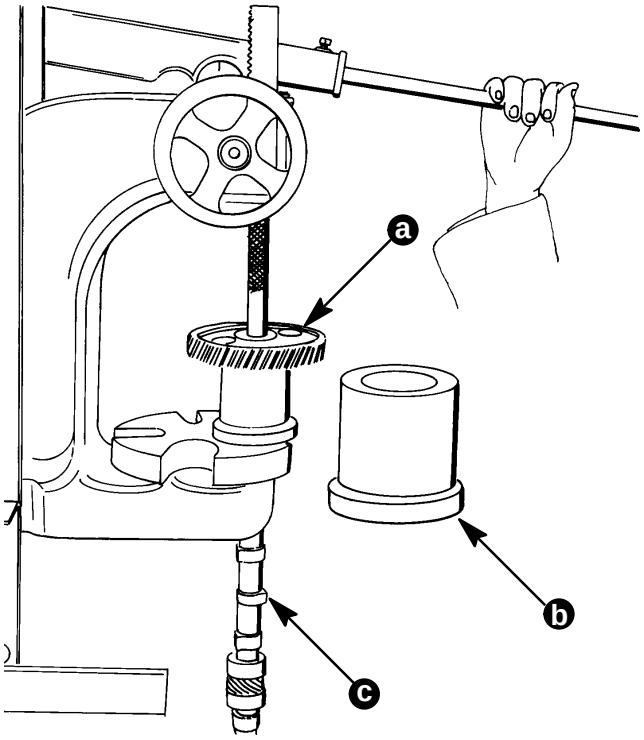
a - Feeler Gauge
b - Camshaft Gear
c - Camshaft Thrust Plate
d - Take Measurement Here

Camshaft Gear Replacement

1. If inspection indicates that camshaft, gear or thrust plate should be replaced, remove gear from camshaft.
2. Place camshaft thru gear remover, place end of remover on table of a press shaft out of gear.

⚠CAUTION

Position thrust plate so that woodruff key in shaft does not damage plate when shaft is pressed out of gear. Also support hub of gear, or gear will be seriously damaged.



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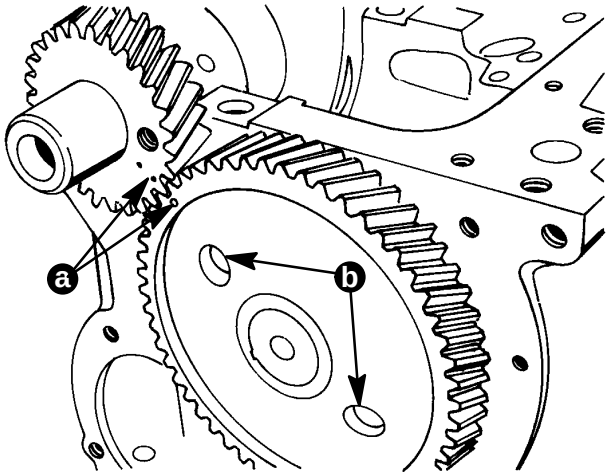
a - Camshaft Gear
b - Support Sleeve
c - Camshaft

Installation

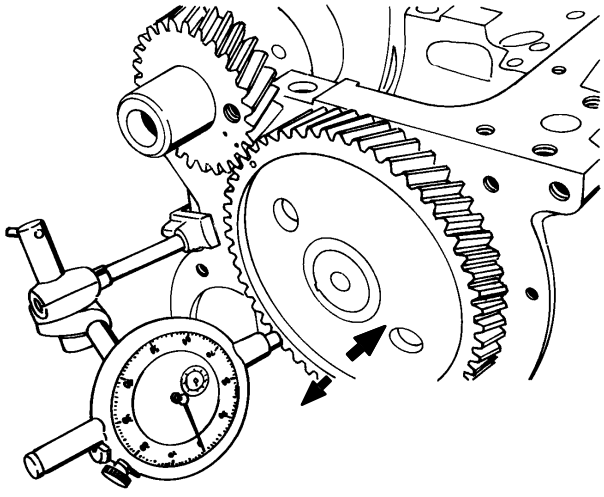
1. Install camshaft and gear assembly in engine block, being careful not to damage camshaft bearings or camshaft.



74438

a - Timing Marks
b - Screw Access Holes

2. Turn crankshaft and camshaft so the timing marks on gear teeth will line up. Push camshaft thrust plate to block screws and torque to specifications.
3. Check camshaft and crankshaft gear run-out with a dial indicator. Camshaft gear run-out should not exceed .004 in. (0.1 mm) and crankshaft gear run-out should not exceed .003 in. (0.07 mm).



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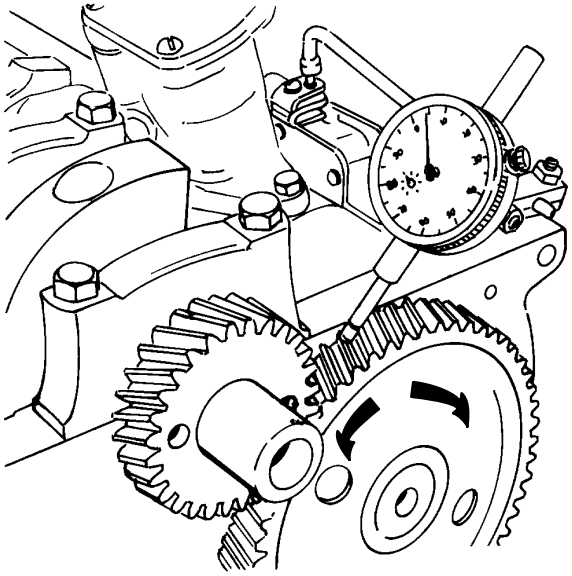
Checking Timing Gear Run-Out

4. If gear run-out is excessive, remove gear and clean burrs from shaft, or gear must be replaced.
5. Check backlash between timing gear teeth with a dial indicator. Backlash should not be less than .004 in. (0.010 mm) or more than .006 in. (0.15 mm)



74441

Checking Timing Gear Backlash

6. Install fuel pump.
7. Install front crankcase cover.
8. Pour G. M. Engine Oil supplement or light engine oil over camshaft lobes and install valve lifters.

Index

Camshaft Bearings

Removal

Camshaft bearings can be replaced while engine is disassembled for overhaul or without complete disassembly. To replace bearings without complete disassembly, remove camshaft and crankshaft, leaving cylinder heads attached and pistons in place. Before removing crankshaft, fasten connecting rods against sides of engine so that they will not interfere while replacing camshaft bearings.

9. With camshaft and crankshaft removed, drive camshaft rear plug from cylinder block.

NOTE: *This procedure is based on removal of bearings from center of engine first, thus requiring a minimum amount of turns to remove all bearings.*

1. Using camshaft bearing remover and installer set (J-6098-01) (with nut and thrust washer installed to end of threads), position pilot in front camshaft bearing and install puller screw through pilot.
2. Install tool with shoulder toward bearing. Be sure a sufficient amount of threads are engaged.
3. Using two wrenches, hold puller screw while turning nut. When bearing has been pulled from bore, remove tool and bearing from puller screw.
4. Remove remaining bearings (except front and rear) in same manner. It will be necessary to position pilot in rear camshaft bearing to remove rear intermediate bearing.
5. Assemble driver on driver handle and remove front and rear camshaft bearings by driving toward center of cylinder block.

Inspection

Clean camshaft bearing bores in cylinder block with solvent and blow out with compressed air. Be sure grooves and drilled oil passages are clean.

Installation

⚠CAUTION

Oil holes in bearings must line up with oil holes in cylinder block. Oil hole is on top side of bearing shell and cannot be seen during installation, so first align bearing shell oil hole with oil hole in bore and mark opposite side of bearing and block at bore to easily position oil hole during installation.

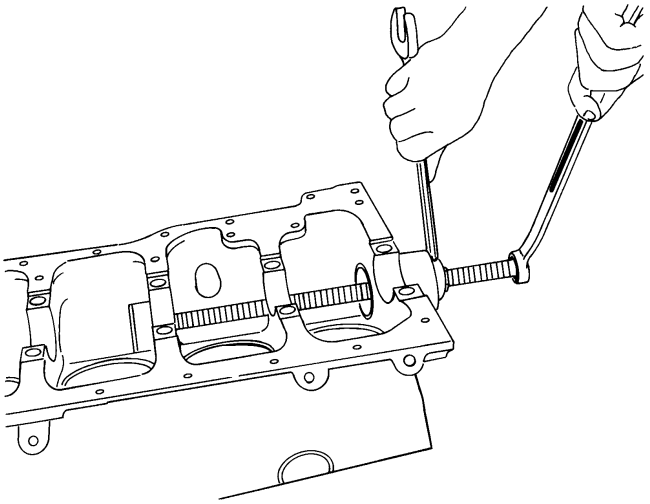
IMPORTANT: Front bearing must be driven approximately .125 in. (3 mm) behind the block face to uncover oil hole to timing gear oil nozzle.

IMPORTANT: All camshaft bearings are not the same. Be sure to install bearings in proper locations (Indicated by bearing manufacturer) and to position bearings as follows (directional references are in reference to engine in its normal operating position):

Lubricate outer surface of new camshaft bearings with engine oil to ease installation.

1. Installing intermediate and center bearings:
   a. Install nut and thrust washer all the way onto puller screw, then position pilot in front camshaft bearing bore and insert screw through pilot.

b. Index center camshaft bearing, then position appropriate size remover and installer tool in bearing and thread puller screw into tool. Be sure at least 1/2 in. (13 mm) of threads are engaged.



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Pulling Cam Bearing From Bore

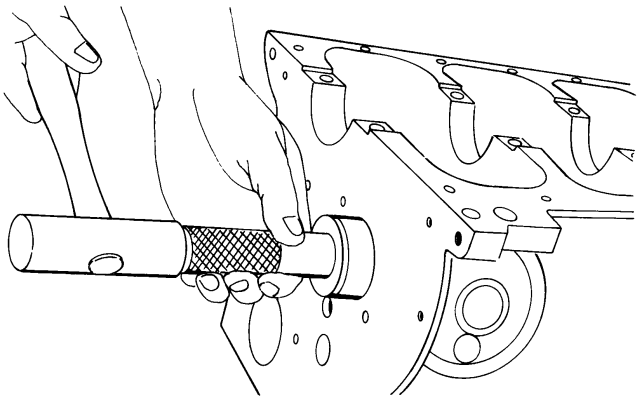
c. Using two wrenches, hold puller screw and turn nut until bearing has been pulled into position. Remove the remover and installer tool and check to ensure that oil hole(s) in bearing are positioned correctly.

d. Install intermediate bearings in same manner being sure to index bearings correctly. It will be necessary to position pilot in rear camshaft bearing bore to install rear intermediate bearing.

2. Installing front and rear bearings:

   a. Install appropriate size remover and installer tool on drive handle.

   b. Index front bearing (as explained in “Important” above), and drive it into position with tool. Check position of oil hole(s) in bearing to ensure bearing is positioned correctly.



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Removal And Installation Camshaft Bearings

a - Installation Tool
b - Camshaft Bearing

   c. Install rear bearing in same manner, being sure to index bearing correctly.

3. Install a new camshaft rear plug.

IMPORTANT: Plug must be installed flush to 1/32 in. (0.8 mm) deep and must be parallel with rear surface of cylinder block.

4. Install crankshaft and camshaft as previously outlined.

Cylinder Block

Cleaning and Inspection

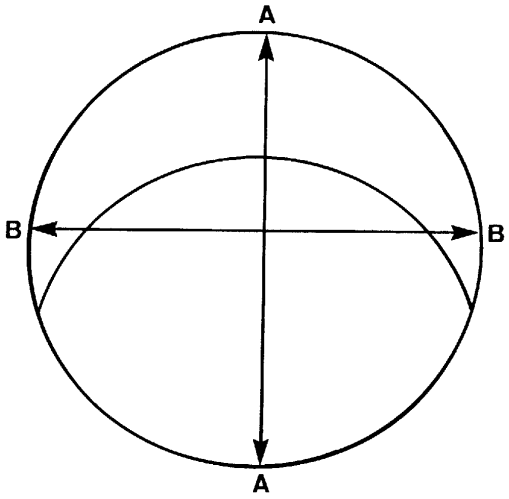
1. Remove all engine components as previously outlined.
2. Wash cylinder block thoroughly in cleaning solvent and clean all gasket surfaces.
3. Remove oil gallery plugs and clean all oil passages.
4. Remove expansion plugs.

NOTE: *These plugs may be removed with a sharp punch, or they may be drilled and pried out.*

5. Clean and inspect water passages in cylinder block.
6. Inspect cylinder block for cracks in cylinder walls, water jacket valve lifter bores and main bearing webs.

⚠CAUTION

Measure cylinder walls for taper, out-of-round or excessive ridge at top of ring travel. This should be done with a dial indicator or inside micrometer. Carefully work gauge up and down cylinder to determine taper and turn it to different points around cylinder wall to determine out-of-round condition. If cylinders exceed specifications, boring and/or honing will be necessary.



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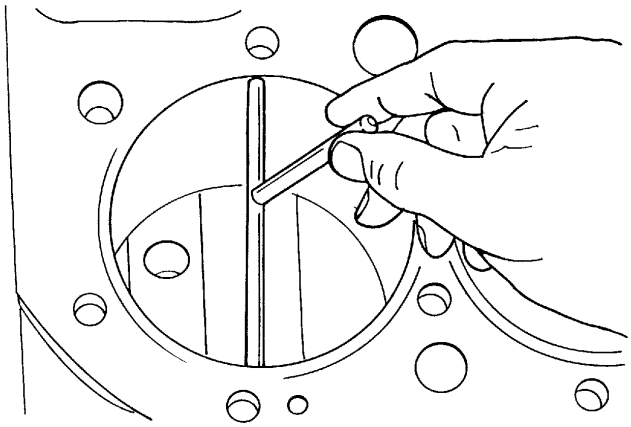
"A" = At right angle to centerline of engine
"B" = Parallel to centerline of engine
"Out-of-Round" = Difference between "A" and "B"
"Taper" =Difference between measurement "A" at top of cylinder bore and "A" measurement at bottom of cylinder bore

Cylinder Measurement



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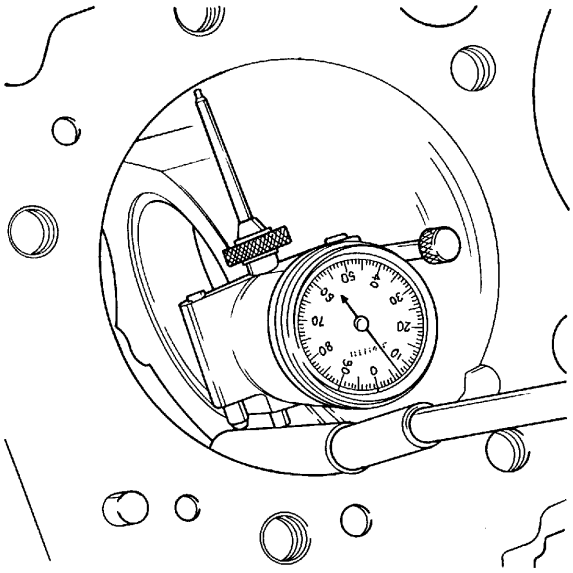
Measuring Cylinder Bore With Snap Gauge



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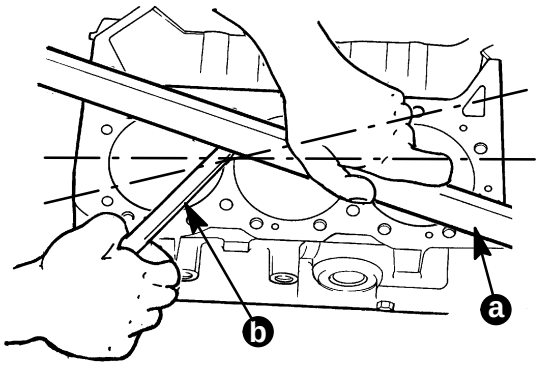
Measuring Cylinder Bore With Dial Indicator

7. Check cylinder head gasket surfaces for warpage with a machinist's straight-edge and a feeler gauge, as shown. Take measurements diagonally across surfaces (both ways) and straight down center. If surfaces are warped more than .003 in. (0.07 mm) in a 6 in. area or .007 in. (0.2 mm) overall, block must be resurfaced by an automotive machine shop.



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a - Machinist's Straight-Edge
b - Feeler Gauge

CYLINDER CONDITIONING

1. Performance of the following operation depends upon engine condition at time of repair.
2. If cylinder block inspection indicates that block is suitable for continued use (except for out-of-round or tapered cylinders), they can be conditioned by honing or boring.
3. If cylinders have less than .005 in. (0.127 mm) taper or wear, they can be conditioned with a hone and fitted with high limit standard size piston. A cylinder bore of more than .005 in. wear or taper may not clean up entirely when fitted to a high limit piston. To entirely clean up the bore, it will be necessary to bore for an oversize piston. If more than .005 in. taper or wear, bore and hone to smallest oversize that will permit complete resurfacing of all cylinders.
4. When pistons are being fitted and honing is not necessary, cylinder bores may be cleaned with a hot water and detergent wash. After cleaning, swab cylinder bores several times with light engine oil and a clean cloth, then wipe with a clean dry cloth.

CYLINDER BORING

1. Before using any type boring bar, file off top of cylinder block to remove dirt or burrs. This is very important to prevent boring bar tilt, with result that bored cylinder wall is not at right angles to crankshaft.
2. Measure piston to be fitted with a micrometer, measuring at center of piston skirt and at right angles to piston pin. Bore cylinder to same diameter as piston and hone to give specified clearance.

NOTE: *Hone cylinders as outlined under "Cylinder Honing" and "Piston Selection," following.*

3. Carefully observe instructions furnished by manufacturer of equipment being used.

CYLINDER HONING

1. Follow hone manufacturer's recommendations for use of hone and cleaning and lubrication during honing.
2. Occasionally, during the honing operation, thoroughly clean cylinder bore and check piston for correct fit in cylinder.
3. When finish-honing a cylinder bore to fit a piston, move hone up and down at a sufficient speed to obtain very fine uniform surface finish marks in a crosshatch pattern of approximately 30 degrees to cylinder bore. Finish marks should be clean but not sharp, free from imbedded particles and torn or folded metal.

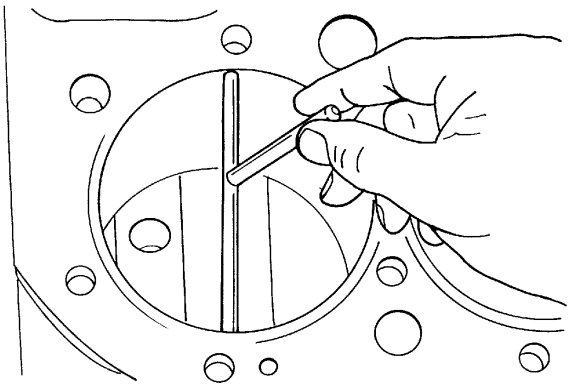
4. Permanently mark piston (for cylinder to which it has been fitted) and proceed to hone cylinders and fit remaining pistons.

IMPORTANT: Handle pistons with care and do not attempt to force them through cylinder until cylinder is honed to correct size, as this type piston can be distorted by careless handling.

5. Thoroughly clean cylinder bores with hot water and detergent. Scrub well with a stiff bristle brush and rinse thoroughly with hot water. It is extremely essential that a good cleaning operation be performed. If any abrasive material remains in cylinder bores, it will rapidly wear new rings and cylinder bores in addition to bearings lubricated by the contaminated oil. Swab bores several times with light engine oil on a clean cloth, then wipe with a clean dry cloth. Cylinder should not be cleaned with kerosene or gasoline. Clean remainder of cylinder block to remove excess material spread during honing operation.

PISTON SELECTION

1. Check used piston to cylinder bore clearance as follows:
   a. Measure cylinder bore diameter with a telescope gauge 2-1/2 in. (64 mm) from top of cylinder bore as follows.



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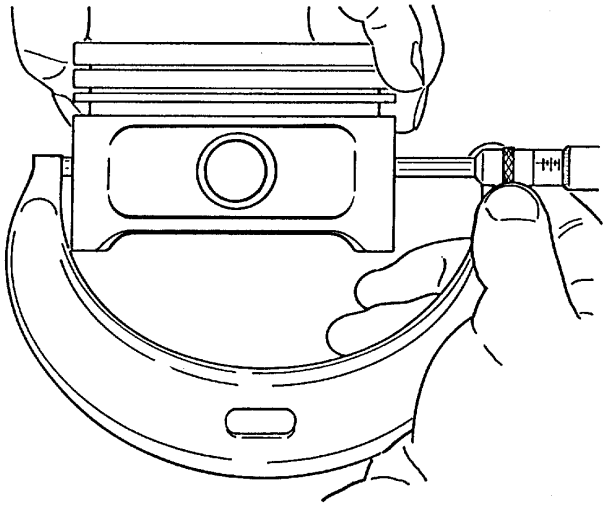
   b. Measure piston diameter at skirt across center line of piston pin as shown.



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   c. Subtract piston diameter from cylinder bore diameter to determine piston-to-bore clearance.
   d. Determine if piston-to-bore clearance is in acceptable range shown in “Specifications.”
2. If used piston is not satisfactory, determine if a new piston can be selected to fit cylinder bore within acceptable range.
3. If cylinder bore must be reconditioned, measure new piston diameter (across centerline of piston pin), then hone cylinder bore to correct clearance (preferable range).
4. Mark piston to identify cylinder for which it was fitted.

Oil Filter By-Pass Valve

Inspection and/or Replacement

With oil filter removed, check spring and fiber valve for operation. Inspect for a cracked or broken valve. If replacement is necessary, pry valve out with screwdriver. Install and seat a new valve by tapping in place with a 9/16 in. thin wall deep socket.